THE INFLUENCE OF INTERNAL CONTROLS ON MANAGEMENT MODELS IN INCREASING THE EFFICIENCY OF PUBLIC WATER SUPPLY

by

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Dedication

Pursuing a Doctorate in Business Administration required countless hours of research, thought, and dedication. It would not have been possible without the support of my family. This work is dedicated to my family, whose support and encouragement have guided me throughout this journey.

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ABSTRACT

THE INFLUENCE OF INTERNAL CONTROLS ON MANAGEMENT MODELS IN INCREASING THE EFFICIENCY OF PUBLIC WATER SUPPLY

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Public water supply in modern times, meaning words, has existed since 1544, when the English parliament brought an insurance law to clear water for citizens in London. In the middle of the 19th century, under the influence of the Industrial Revolution, cities were rapidly developed, and the number of inhabitants and economic activities grew due to the need for water. With accelerated growth in population, urbanization, polluted environment, and already those present effects of climatic change, it is getting harder to ensure and keep enough drinks water. Water supply companies face a challenge to establish a balance between efficient distribution water supply mesh and efficiency in using natural, human, financial and other resources, a responsible are for realization goals sustainable and effective of business. The problem of efficiency and sustainability of public water supply is a global problem, and water loss is generally considered an important question. Losses of water present in all water supply systems are caused by a series of operational and procedural reasons, especially the fact that in most water supply organizations losses, water with time growing or others in words efficiency quiet organization decreases. Water supply

systems have become more prominent, and everything is older. Because of that, they are, consequently, all more complex for monitoring, management, and maintenance. Repercussions like that state are continuous growth negative indicators of the business. In their efforts to improve your business, water supply companies use different approaches that mostly bring down rehabilitation breakdowns in the fight against water losses. Loss management will be water successful only if introduced as part of the whole sustainable package measure defined long-term strategy. At the same time, when the working group strives to find solutions to increase the efficiency of public water supply, two new ones appeared in the global economic field, each with an independent concept, which entries significant improvements in business economic subjects. Concepts of Lean and Green Management and Industries 4.0 are becoming imperative success businesses and are not deviously part of the production environment but are leading production strategies worldwide. By applying principles of Lean and green management and digitization business based on new ICT technologies, they improved existing methods for efficient water supply management. By occasionally recognizing potential risks and introducing new processes, you reduce the same to an acceptable level, and we influence the efficient water supply system management.

TABLE OF CONTENTS

Contents

List of Figures x

CHAPTER I: INTRODUCTION 1

- 1.1. Introduction 1
- 1.2. Significance of Study 4
- 1.3. Research Questions 6
- 1.4. Objectives 6

CHAPTER II: REVIEW OF LITERATURE 7

- 2.1. Introduction 7
- 2.2. Internal Controls 7
- 2.3. Control Environment 10
- 2.4. Risk Assessment 11
  - 2.4.1. Analyzing Risks 12
  - 2.4.2. Managing Risks 12
- 2.5. Control Activities 12
  - 2.5.1. Preventive Controls 12
  - 2.5.2. Detective Controls 12
  - 2.5.3. Corrective Controls 12
- 2.6. Information and Communication 13
- 2.7. Information Systems 13
- 2.8. Monitoring and Reporting 13
- 2.9. Separate Evaluations 13
- 2.10. Public water supply 14
- 2.11. Sustainability of the public water supply system 15
- 2.12. Effectiveness of Public Water Supply Systems 16
- 2.13. Actual water losses in water supply systems 21
- 2.14. DMA Zone 24
- 2.15. Legislative framework 26

CHAPTER III: METHODOLOGY 27

- 3.1. Overview of the Research Problem 27
- 3.2. Research Problem and Questions 32
- 3.3. Data Collection Procedures 39
- 3.4. Research Design 41
- 3.5. Conclusion 44

CHAPTER IV: RESULTS ... 46

4.1. Design Control Activities ... 46
4.2. Digitizing Public Sector Water Supply Operations ... 47
4.3. DMA Zone ... 54
4.4. Detection and location of water losses ... 57
4.5. Digitization of business in the industry of public water supply ... 60
4.6. Guidelines for the development of advanced network infrastructure ... 64
4.7. Development of the "Smart grid" ... 64
4.8. AWMR-VIO pilot projects ... 65
    4.8.1. Pilot project 1 ... 66
    4.8.2. Pilot projekt 2 ... 70
    4.8.3. Pilot projekt 3 ... 73
    4.8.4. Pilot projekt 4 ... 74
    4.8.5. Pilot projekt 5 ... 76
4.9. Development and implementation of a new system for remote reading of water meters – AWMR ... 77
4.10. Basic components of the local AWMR network (LAN/HAN) ... 79
4.11. Long-distance wireless network ... 81
4.12. Central system for reading water meters ... 82
4.13. Application MARS ... 83
4.14. Planning the long-distance network (ULP) ... 85
4.15. Integration of AWMR with SDM ... 87
4.16. Installation plan for AWMR equipment ... 88
4.17. Standards and legal acts related to water meters ... 89

CHAPTER V: DISCUSSION ... 90

5.1. Design of the WALEGRIN 4.0 model ... 90
5.2. Key performance indicators of water supply organizations ... 93
    5.2.1. Guidelines for Better Utilization of Employee Potential ... 96
    5.2.2. Guidelines for Reducing Water Losses ... 96
    5.2.3. Guidelines for Better Inventory Management ... 97
    5.2.5. Organizational structure and development of supporting processes VIO ... 98
5.3. Organization of the Information and Telecommunications Process ... 98
    5.3.1. Organization of Support Processes ... 100
5.4. Water Loss Reduction and Financial Savings Plan ... 103
5.5. How to start a project ... 103
5.6. Project risk management ... 104
    5.6.1. Project risk register ... 105
    5.6.2. Internal audit activities ... 106
    5.6.3. Expectations of Internal Control ... 107
    5.6.4. Role of Internal Audit ... 107

5.6.5. Undertaking an Internal Audit 108
5.6.6. Allocation of Responsibilities.. 108
5.6.7. Five lines of assurance 108

CHAPTER VI: SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS....... 111

6.1. Summary 111
6.2. Recommendations for Future Research 114
6.3. Conclusion.. 115

List of Figures

Figure 3.3 Mobile device for collenting for meter reading (DOLPHIN 7900) 37

Figure 3.4 M-BUS, Secondary water meter at location Vrbani III, Kutnjački put 10 38

Figure 3.5 Population movement in the world until 2050 - the population that will live in cities. 39

Figure 3.6 M-BUS, Principal scheme and method of connecting AMR to the billing system 40

Figure 3.7 Concept of neoprene network 43

Figure 4.1 SMART water supply connection concept 51

Figure 4.2 Innovative CPS water supply network concept 53

Figure 4.3 Schematic representation of the DMA zone 55

Figure 4.4 DMA-based water network architecture 56

Figure 4.5 Invisible water leakage at the detected fault location.. 58

Figure 4.6 Breakage of the water supply pipeline 58

Figure 4.7 Fault not detected in time – indirect damage 59

Figure 4.8 Application of IoT and BIG DATA in water supply 62

Figure 4.9 Spatial layout of selected locations 1. Pilot project Knežija-Jarun 67

Figure 4.10 Schematic representation 2. Pilot project 71

Figure 4.11 Display of the Mamutica Complex 74

Figure 4.12 Internal UZV water meters 75

Figure 4.13 Spatial representation of the covered area in the Vrbani 3 SDM project 77

Figure 4.14 The fundamental concept of the smart AMR network for reading water meters 78

Figure 4.15 Access point at the water reservoir VIO - Water reservoir Biškupec Breg 82

Figure 4.16 Modules of the MARS application 84

Figure 4.17 Spread of RF signal ULP from AP-Biškupec Breg 86

Figure 4.18 Planning APs ULP for the City of Zagreb 86

Figure 5.1 A landscape-scale perspective of CPS applications in water management. CPS are embedded across the water cycle. Most CPS have a sensing layer (sensor nodes, drones, satellite images, etc.), a data transmission layer (i.e. WLAN, fiber networks, etc.), an application layer (cloud service, databases.) and an intelligent application layer for monitoring data, emergency response and evaluation [20]. Source: original image concept created by the Authors for this paper with graphic design work carried out by scientific illustrator Cate Broadbent. 92

Chapter I:
INTRODUCTION

1.1. Introduction

Contemporary corporate management approaches and models prioritize minimizing resource wastage and eliminating non-value-adding waste generation in products and services. Water utilities often produce more water than end consumers require, leading to considerable water loss in the distribution systems, which prompts excessive water production. Water losses are categorized into actual, economically justifiable, and unavoidable losses. The definition of economically justifiable losses varies based on numerous factors and must be regularly assessed by the water company for future planning. Over time, such justifiable losses should consistently be reduced to the threshold of inevitable losses. Additionally, inventory management poses a challenge for water utilities with the common issue of surplus stocks, significantly impacting losses. Necessary inventory supporting the core functions and maintenance of predominantly subterranean water networks require meticulous activity planning and allocating adequate human and material resources. Water companies, aiming to keep the water supply highly available, tend to accumulate excess inventory as a safeguard. Moreover, the intricacies of public procurement laws, including procedures like tenders and their associated risks, contribute to this overstocking, leading to bloated inventories and inflated operational costs from excessive storage space and personnel. Aging or improperly stored inventory often results in further losses through write-offs. The surplus stock issue can be mitigated with better planning, especially for indispensable items that are difficult to procure. Readily available items stocked for non-core activities represent unnecessary inventory. Adopting a Just-In-Time (JIT) procurement strategy can ensure the accessibility of materials essential for day-to-day operations without the burden of overstocking. Furthermore, outsourcing non-essential activities can effectively reduce surplus inventory needs. Transportation losses in water utilities are perceived from two distinct viewpoints. Firstly, transportation losses within water distribution systems are those incurred while delivering water from the initial source, like a pumping station, to the end consumer. Optimal network design, supported by mathematical modeling, is initiated in the planning phase to address these losses, which manifest as wasted water, energy losses, pressure drops, or suboptimal water flow. Upon construction, these transport losses are managed and minimized through the real-time monitoring of physical and chemical parameters and informed decision-making based on mathematical models. Secondly, transport losses within water utility operations include the unnecessary movements of personnel, vehicles, and machinery. The territory of water utility services varies from small areas to vast metropolitan or intercity regions, determining the extent of transportation needed for system management and maintenance. Effective planning and fleet management software can optimize these activities, reducing related losses. Waiting The water supply system operates continuously around the clock every day of the year. Service interruptions may occur due to disconnection for repairs or subpar water quality. However, inefficiencies such as a poor corporate culture, lack of standardized procedures, and unavailability of necessary parts and materials lead to delays in:

I. Establishing new connections,
II. Diagnosing and fixing issues,
III. Overhauling the water supply infrastructure.

Management inefficiency and a lack of standardized work processes result in unnecessary movements when establishing new connections. Nonrevenue water encompasses all water not billed, with a portion being unavoidable, including water allocated for firefighting; water for firefighting is utilized spontaneously and cannot be regulated. Technological water is used to flush the distribution systems, especially in outlying areas where water quality may diminish due to stagnation. Flushing can be optimized by contracting large water users, like firefighting units and sanitation companies, which can fulfill their needs and system maintenance. Any other water that is lost equates to direct loss, categorized as:

I. Apparent losses: from inaccurate metering or unauthorized use,
II. Actual losses: from leaks and breaks in the network.

However, advanced water supply systems, like Berlin's, can be managed without reservoirs using sophisticated equipment, achieving optimal resource utilization.

Water companies might resist change, overlooking advancements in management and Houman Resource. Widespread issues include:

I. Poor organizational structure,
II. Excess of managerial staff without clear roles,
III. Inefficient job descriptions,
IV. Inadequate performance review regulations,
V. Inequitable compensation,
VI. Underutilization of employees' skills,
VII. Lack of professional growth opportunities,
VIII. Insufficient internal and external training,
IX. Promotions do not reflect actual work performance.

High electricity consumption is closely linked to the overproduction of water, causing significant financial drains in water utility companies. Slashing water wastage translates to immediate energy savings—wasteful energy practices. Financial gains are possible by fine-tuning pump station operations to coincide with periods of lower electricity rates, such as overnight when filling reservoirs—cost reduction through enhanced pump station operations when the electrical grid is less stable. Savings are realized through strategic electricity procurement and establishing optimum schedules. Adjusting the pump stations (major power consumers) on or off as the utility company directs during high or low electricity demand aids grid stability. Water systems stay balanced based on the reservoirs' time constants—potential savings from utilizing renewable energy sources. The defense against contamination of water pump stations is mandated by law by establishing protection zones. The first zone encircles the pumping station, and its size is determined by the extent of the aquifer, environmental factors, and possible contamination sources. Typically, these are expansive areas where only water-related operations are permitted, although generating solar power for internal consumption is allowed. Water utilities are restricted to providing public water supply services and are therefore enabled to produce and consume their renewable electricity (via solar photovoltaic systems), aligning with sustainable practices. Case studies include Berlin's power plant at a water station and Zagreb's approved "Mala Mlaka" solar plant project, with a 9.9 Megawatts capacity.

Water waste in supply systems often arises from excessive production tied to the low energy efficiency of water utilities' old and poorly maintained facilities, leading to substantial water loss. Process water dispensed from the supply system without billing for pipeline flushing is a normative practice. Flushing usually occurs at the network's edges where there is scarce use, and water quality may diminish (stagnant water). Optimizing process water usage, including double utilization, is conceivable through improved contract management and coordination, explicitly targeting refilling sites for fire trucks and street cleaning vehicles. Materials:

Chemical substances, such as chlorine, are integrated into water treatment at the introduction point into the distribution system. This practice requires adherence to rigorous legal standards due to chlorine's high toxicity levels. Conversely, employing physical procedures for water treatment is deemed more favorable for human and environmental health and proves to be economically beneficial, being both less expensive and less complex. Water conduits should be comprised of materials deemed safe and sustainable. Acceptable conduits are those fabricated from inert and recyclable substances with expected durability surpassing 100 years, such as those created from gray or ductile cast iron. Historically, asbestos-cement conduits have demonstrated considerable shortcomings, now prompting their prohibition; these conduits were notably detrimental during manufacturing due to asbestos use, had a service life under 40 years, and were exceptionally prone to damage from construction work, seismic events, and both static and dynamic pressure stresses. Replacing conduits in water supply network restoration demands careful material selection since the cost of piping represents less than 10% of the total rehabilitation expenses. All waste produced during water supply activities, including network replacement, reconstruction, and upkeep, must be handled and eliminated in compliance with regulations governing the disposal of specialized waste types. Adequate records, including reports and disposal documentation, must be maintained.

1.2. Significance of Study

The provision of public water encompasses the processes of collecting water from underground and surface sources, treating it to make it potable, fulfilling the requirements for drinking, food preparation, hygiene, community, and industrial uses, and transporting this water from the source to the end user Challenges such as rapid population increase, urban development, environmental contamination, and climate change's current impacts complicate ensuring an adequate drinking water supply. The European Commission's reference document states that water is a crucial natural resource that needs sustainable management, and any loss should be consistently minimized. Water utilities are tasked with finding the right balance between efficient water distribution networks and the prudent use of natural, human, and financial resources while striving for sustainable operations. Water supply infrastructure, also called the water supply system, comprises the construction, tools, and equipment used for water provision. This includes the acquisition, treatment, delivery, and distribution of water for consumption, food prep, hygiene, communal, and economic activities, extending from the origin to the end user. Water treatment refers explicitly to monitoring and improving water that does not meet quality standards. It is vital to provide a reliable supply of safe drinking water to the consumer base to fulfill the demands of those within the service area of the water supply network. Water delivery systems may be either communal, serving individual communities with water sources nearby, or regional, where water is transported over greater distances from more remote sources due to insufficient local resources. Systems delivering water are classified based on the energy used to achieve necessary pressure, falling into gravitational, pressurized, or combining both types. Gravitational systems utilize the natural potential energy from high-altitude sources, whereas pressurized systems rely on pumps where natural gravity is inadequate, often for wells and underground sources. The sustainability of public water supply can be assessed through four main pillars: social, economic, environmental, and technical.

The sustainability of water supply on a social level is paramount, considering water's status as an essential human need alongside air and food. The World Health Organization has set forth guidelines for drinking water quality to safeguard public health. Access to a sufficient, safe, and reachable water supply is fundamental to life and must be equitable. Enhancing drinking water access can bring vast public health improvements, hence the push for the highest possible drinking water quality. Tailoring these guidelines to local or national environmental, societal, economic, and cultural contexts is essential. Thus, the social dimension of public water supply sustainability is not only a health concern but a political one, with the aim being universal access to clean water at a reasonable cost.

Public water access should meet community needs within the boundaries of local and national environments, societal norms, economic constraints, and cultural values. The availability of such supplies is dictated by EU directives mandating that by 2020, every settlement with over 50 residents should be connected to a public water system. Factors like unavailability, excessive costs, or insufficient water quantity and quality highlight the social unsustainability of public water supply systems. World Health Organization's guidelines state that the economic dimension of sustainability is equally a political and social concern. Organizations that provide water services must operate economically and efficiently, ensuring financial equilibrium over time. In Europe, such economic sustainability is governed by EU regulations, notably Directive 2000/60/EC and Directive 98/83/EC. These regulations mandate that public water supply enterprises focus exclusively on supplying water, maintaining independence, and prioritizing covering costs over generating profits. Income derived from water sales should adequately compensate for expenses associated with supplying water, which includes energy, upkeep of water infrastructure, amortization, and employee salaries. Capital for constructing water infrastructures comes from water supply development fees (included in water pricing) and subsidies from local government budgets and EU contributions.

The environmental dimension of sustainability highlights the role of public water supply systems in harvesting underground and surface water and processing it for consumption, culinary use, sanitation, and other community and economic purposes. It also involves the transportation and distribution of water to consumers. To prevent undesirable effects, water supply entities must prioritize preserving water sources, including underground water extraction sites and surface water collection points. Pollution prevention involves implementing sanitary protection zones and additional necessary actions. Water withdrawals must be managed to guarantee the enduring viability of water sources. This environmental consideration becomes particularly crucial in areas with inadequate water supplies.

The technical dimension of sustainability encompasses the complex nature of water supply systems, which rely on ample human expertise and material resources to operate sustainably. Most existing systems are over a century old and are aging, necessitating competent management as well as proactive and, less frequently, reactive maintenance. Components incurring unsustainable maintenance costs or those needing excessive reactive maintenance should undergo rehabilitation. Sustaining an adequate water supply system management is crucial. These facets of sustainability are interlinked, and water losses in the public system harm the environment and lead to greater water extraction, raising energy and maintenance costs and, by extension, impacting economic sustainability. Inefficient systems result in higher water pricing, undercutting social sustainability. Water utilities aim to balance proficient water distribution and reasonably utilize natural, human, and financial resources to promote sustainable operations. Relevant literature includes outlining water supply sustainability challenges in developing nations.

Rapid urban population growth—spurred by migration, commerce, tourism, and other factors—has led to overpopulation and the pressing need to provide ample potable water. Their work examines environmental concerns regarding drinking water in developing countries and presents studies to discern practical approaches to public water supply issues.

1.3. Research Questions

As an internal auditor working in Vodoopskrba i Odvodnja d.o.o., a public water supply company, I consistently encountered challenges and a lack of anticipated improvements in business processes—the search for solutions led to reconsidering ingrained behavioral patterns. With the potential for change hinging on the application of various strategies and approaches, it is vital to study the practices of prosperous enterprises to discern the behavioral patterns underpinning their achievements. The "Lean management" approach has gained worldwide recognition as an effective behavioral model, widely adopted by leading businesses to optimize their operations. Similarly, firms embracing the "Industry 4.0" philosophy and advancing their operations through digitalization demonstrate commendable patterns. Numerous companies have elevated their performance by integrating these models, delivering higher-quality products and services more efficiently in labor, space, capital, and time. This insight propelled further exploration into the potential enhancements and adaptations within the public water supply sector through these concepts, evaluating their impact on augmenting operational efficiency. Equally significant is the imperative to explore, spurred by the united call of experts and organizations concerned with public water systems, to develop and implement efficacious methodologies for curtailing water losses within actual water supply networks.

1.4. Objectives

Considering the insights highlighted in the introductory section, the public water supply sector has not kept pace with contemporary knowledge and technological advancements. The industry has much to gain from adopting Lean and Green Management methodologies, coupled with adopting intelligent technologies under the umbrella of Industry 4.0, broadening the prospects for novel research and implementation opportunities. Embedding Lean and Green strategies, state-of-the-art knowledge, and intelligent technologies into a comprehensive management model will pave the way for the evolution of the water supply system. This research will build the foundation for a cohesive management framework to enhance the functionality of the public water supply, focusing on optimizing performance, trimming operating expenses, offering innovative management and maintenance approaches, and uplifting the service quality of public water suppliers. Activities revolving around the construction and augmentation of the public water supply infrastructure are excluded from this study, as they are governed by specific legislation and regulatory directives and thus fall outside this project's scope.

Chapter II:
REVIEW OF LITERATURE

2.1. Introduction

Despite developing various methods and tools to increase the efficiency of water supply systems and reduce water losses, the results often fall short due to public water supply organizations' resistance to accepting new knowledge and making consistent changes. The European Commission's reference document underscores the importance of managing water as a valuable natural resource in a sustainable manner while minimizing any loss of this vital resource. Public water supply organizations are tasked with balancing distribution network efficiency and the responsible use of natural, human, financial, and other resources to achieve sustainable business goals. Challenges such as population growth, urbanization, and climate change make ensuring an adequate water supply for human consumption increasingly tricky. The World Health Organization highlights the significance of including water losses in a comprehensive, long-term water resources management plan, especially in areas with limited natural resources. Excessive water losses, depicted as wasteful, lead to inefficiency within water supply organizations. Consequently, reducing water losses is pivotal to the success of water supply organizations, as emphasized by the World Health Organization and the World Bank. Addressing the concern of water leakage from distribution networks of water supply systems is a global issue, warranting a practical methodology for mitigating water losses to be proposed and implemented across water supply systems. Overall, water losses are a crucial indicator of the success of water supply organizations, reflecting the global challenge of efficiency and sustainability in public water supply.

2.2. Internal Controls

Hamed (2009) describes the Internal Control System as a structured combination of processes within a comprehensive set of controls instituted by management to ensure the effective operation of a company. Keitany (2000) details these controls as methods and measures employed by the management to safeguard assets, prevent fraud, and facilitate the timely production of valuable financial information, fostering optimal collaboration with the company's director. Echoing this sentiment, Hongming and Yanan (2012) liken the Internal Control System to a pervasive neural network within a company, transmitting instructions and feedback between the management and various departments, closely interwoven with the firm's organizational structure and overarching policies. Whittington (2001) expands this definition, contending that internal control transcends solely accounting or financial interests, representing a systematic approach to assessing the alignment between established benchmarks and actual organizational outcomes.

According to the Auditing Practices Committee (1980), Internal Control involves the objective assessment and validation of the company's financial management by an appointed auditor, governed by the pertinent legal standards of the time. Therefore, the goal of Internal Control is twofold: providing superior service levels to management and supporting organizational members for more effective execution of their roles. Schleifer and Greenwalt (1996) argue that Internal Controls are valuable tools that enhance the organization's functionality, fostering a more systematic and integrated operational approach when appropriately implemented.

Rezaee (2002) posits that internal controls are vital strategies organizations enact to achieve desired ends and safeguard the organization's mission and objectives. These controls include a range of policies and procedures designed to handle transactions accurately, thus preventing wastage, theft, and misuse of resources. Organizations achieve performance targets and goals through adequate internal controls, maintaining resource integrity, fostering accurate reporting, and ensuring regulatory compliance. Consequently, organizations actively strive to refine their Internal Control systems in response to the evolving economic landscape, competitive pressures, customer preferences, and the need to boost revenue (Kantzos & Chondraki, 2006).

Internal control comprises five interconnected elements that stem from the management's operational style and are embedded within the managerial process: the control environment, risk assessment, control activities, information and communication, and ongoing monitoring (Carmichael, 1996). Liu (2005) and Rittenberg et al. (2005) categorize the significance of internal control into six key areas: the detection of errors and fraud, the reduction of unlawful activities, the enhancement of company efficiency, the improvement of information quality, the establishment of business infrastructure, and the potential for lowering audit costs.

Adopting comprehensive internal control systems in the public sector is crucial due to the inherent complexities and the accountability required to handle public resources. A robust internal control environment helps mitigate fraud and corruption and improves organizational performance. As highlighted by the OECD, effective internal control systems contribute significantly to risk management and audit processes across public sector entities, supporting governance structures by fostering transparency and accountability (OECD.org - OECD).

Institutional frameworks and practices also underpin the strength of internal controls. As the World Bank outlines, performance-based accountability systems, especially in previously weak accountability structures, can be strengthened by enhancing the role of representative institutions and oversight bodies. These bodies are essential in monitoring government programs and ensuring that internal and external accountability mechanisms are effectively utilized to combat corruption and improve efficiency (Open Knowledge. World Bank).

Overall, the effectiveness of internal controls in the public sector is deeply intertwined with the broader organizational culture, leadership commitment, and systematic approaches to performance and risk management. Such systems are not only about compliance but are integral to public sector organizations' strategic management and operational efficiency, ultimately leading to improved public trust and governance outcomes.

A study conducted by Aikins (2008) in the United States 2008 aimed to analyze the impact of government internal audits on enhancing financial performance. This study sought to understand how the efforts of government internal audits contribute to improvements in government financial performance. Despite the expertise of internal audit in assessing the efficient use of economic resources and enhancing oversight and financial performance, there has been limited focus on the role of internal audit in the financial management process within public administration research.

Puttick (2001) defined internal controls as a set of organizational policies and approved internal processes crafted by management to ensure the seamless operation of the business. He further elaborated that a business functions smoothly when it adheres to management policies, safeguards the organization's assets, and establishes a system to prevent and eliminate manipulation of accounting information.

Doyle et al. (2007) studied the factors contributing to weaknesses in internal control over financial reporting. Their research examined the determinants of material weaknesses in internal control over financial reporting using a sample of companies that disclosed such shortcomings. The findings indicated that material weaknesses in internal control are more likely for smaller, less profitable, more complex, rapidly growing, or restructuring firms. These determinants were found to vary in strength based on the type of material weakness disclosed, suggesting challenges in financial reporting controls due to limited resources, complex accounting issues, and a rapidly changing business environment.

Ge and McVay (2005) discovered that poor internal control is often related to inadequate resource allocation for accounting controls, such as a lack of accounting personnel. Specifically, management attributes material weakness in internal controls to insufficient training and deficiencies in the period-end reporting process and accounting policies.

Okuda et al. (2013) investigated Japan's Internal Control Systems and Audit Quality determinants. Their study revealed that firms with good prospects and risky profiles tend to have a negative attitude towards establishing strong internal controls, while firms experiencing significant growth and needing solid internal controls do not consistently hold a negative attitude, often evaluating internal controls positively. The study also highlighted that firms facing pressure from outside creditors are more likely to establish internal controls.

Ewa and Udoayang (2012) explored the impact of internal control design on banks' ability to investigate staff fraud and fraud detection in Nigeria. They found that a robust internal control design dissuades staff fraud, while a weak one exposes the system to fraud and creates opportunities for staff to engage in fraudulent activities. The study emphasized the necessity of an effective and efficient internal control system in the banking sector.

Mawanda (2008) examined the effects of internal control systems on financial performance in higher learning institutions in Uganda. The study established a significant relationship between internal control systems and financial performance, emphasizing the role of the internal audit department in establishing controls that impact organizations' economic performance.

Onyango (2014) emphasized the challenges faced by county governments in Kenya during internal performance controls, such as delayed financial reporting, fraud, and misuse of institutional resources.

Musya (2014) investigated the influence of internal controls on revenue collection by county governments in Kenya, concluding that internal controls indeed affect revenue collection.

Mwachiro (2013) studied the effects of internal controls on revenue collection at the Kenya Revenue Authority, revealing that weak internal controls have facilitated collusion to commit fraud, leading to revenue loss and embezzlement. The study concluded that there is a significant relationship between internal controls and revenue collection at the Kenya Revenue Authority.

2.3. Control Environment

In the realm of internal control, the control environment establishes the organizational ethos by shaping the control awareness of its personnel (Whittington & Pany, 2001). It serves as the cornerstone for all other facets of internal control, encompassing elements such as the integrity and ethical values of those responsible for devising, implementing, and overseeing the controls, as well as the dedication and proficiency of individuals fulfilling their assigned responsibilities, the board of directors or audit committees, management principles and operational approach, and the organizational framework. While numerous factors contribute to the control of environment, its effectiveness is heavily influenced by the board of directors' performance, management, and the organization's audit division. Internal auditors play a crucial role in fostering an effective control environment, as the efficacy of these factors predominantly hinges on their interactions with internal and external auditors. The control environment establishes the organizational ethos, shaping the control awareness of its personnel (Aldridge & Colbert, 1994). Furthermore, it is influenced by the organization's history and culture, exerting a subtle influence on structuring its activities, thus fostering a positive and supportive attitude towards internal control and conscientious management.

To achieve the entity's objectives, management assigns responsibility and delegates authority to critical roles. A key role is a position in the organizational structure assigned to an overall responsibility of the entity. Generally, key roles relate to senior management positions within an entity. Management considers the overall responsibilities assigned to each unit, determines what key roles are needed to fulfill the assigned responsibilities and establishes the key roles. Those in critical roles can further assign responsibility for internal control to roles below them in the organizational structure but retain ownership for fulfilling the overall responsibilities assigned to the unit.

2.4. Risk Assessment

It can also be said that risk assessment is the process of identifying, analyzing, and clearly managing risks that pose a threat to achieving an organization's business objectives. This is dynamic and iterative, but these are the steps:

Identifying Risks In the complex process of identifying potential risks, organizations must adopt a holistic approach that thoroughly examines both internal dynamics and external influences that may significantly impact their operations. This entails recognizing the inherent vulnerabilities within the organization—such as weaknesses in processes, personnel, and systems—and paying close attention to external factors, including market fluctuations, regulatory changes, and socio-economic trends. Such a comprehensive understanding is crucial for developing a nuanced awareness of the organization's landscape. Moreover, organizations need to implement a continuous monitoring system, allowing them to stay attuned to the ever-evolving nature of risks. This proactive stance enables organizations to swiftly adapt their strategies as conditions change rather than simply reacting to threats after they arise. By fostering an agile risk management framework, organizations can effectively prioritize their resources and efforts to promptly address the most pressing issues. Ultimately, this diligent approach to risk management cultivates a resilient organizational environment where ethical practices can flourish, even in the face of uncertainty. By prioritizing adaptability and vigilance, organizations safeguard their operations and set a strong foundation for sustainable growth and integrity, empowering them to navigate challenges with confidence and responsibility. In conclusion, fostering a robust risk management culture empowers organizations to make informed, strategic decisions that align with their core values. By continually assessing risks and reinforcing ethical practices, businesses can build resilience, ensuring they remain responsive and responsible in an ever-changing landscape.

The first phase of Risk assessment is the identification part, which includes all risks that might happen to humidifiers. Find out more: Organizations must determine the internal and external factors that may affect their objectives. This might be done through brainstorming sessions, surveys, scenario analysis, and review of historical data, among other methods.

2.4.1. Analyzing Risks

Once you have identified the risks, analyze their potential impacts and the likelihood of their happening. This process traditionally combines qualitative and quantitative assessment techniques to sort out risk so management can focus on the few with which they are most concerned.

2.4.2. Managing Risks

Management must decide what to do about those risks after they are identified and analyzed. This may involve avoiding, reducing, sharing, or accepting risk. The strategy chosen should be consistent with the organization's risk appetite and total strategic goals.

2.5. Control Activities

Control activities are actions management has established through policies and procedures, which help ensure management's directives to mitigate risks. They are essential as they help in addressing risks Eye opener to figure out more A few controls such as Preventive, Detective, and corrective control

2.5.1. Preventive Controls

Preventative controls are designed to prevent errors or fraud from occurring. For instance, approvals, authorizations, and duties segregation. These controls are proactive and stress quality assurance.

2.5.2. Detective Controls

Detective controls are established to detect the existence of errors or irregularities. Detective controls frequently involve reconciliations, performance reviews, and audits. They will not prevent problems but are crucial for early detection.

2.5.3. Corrective Controls

Corrective controls are to correct any errors or irregularities found quickly. This does result in measures to handle issues quickly and effectively, which helps reduce the damage that can be done with vulnerabilities.

2.6. Information and Communication

Communication for information flow in an organization is any communication related to the processes and systems that help transfer information. Great internal control involves such things as good information made available to those who need it, doing this shortly after an event occurs and before performance results are irreversibly set in plaster since once, they harden into a specific shape, the game is over; apparent communication that everybody can understand. Internal control is only as reasonable as the communication used to maintain effectiveness, not solely within between functions comprising a single corporate organization but through channels across shareholders, regulators, and broader stakeholder audiences. That includes setting up regular communication outlets and ensuring all key stakeholders receive timely information on significant developments and decisions.

2.7. Information Systems

An information system should obtain all the valid internal and external data for appropriate readvertising to achieve its control objectives. Ex: Financial, operational, and compliance data. They allow the systems to cater to numerous stakeholders and balance correct data entry and system security.

2.8. Monitoring and Reporting

Monitoring activities are the organization's ongoing and periodic performance assessments against its criteria. This ongoing exercise ensures that the exercises serve as designed and that the controls are tuned based on performance and new risks. Continuous monitoring is performed as part of the routine course of business, with segmentation for average supervisory and management review, plus other activities personnel take under their day-to-day duties. Deficiency reporting is a crucial part of monitoring. Where deficiencies are found, they need to be reported upwards and ultimately (for major issues) up the chain through management or the board of directors.

2.9. Separate Evaluations

Segregation of duties allows for independent evaluations, which are regular reviews to see if the controls in place effectively work (e.g., internal audit or external auditors). These assessments are done independently, analyzing control processes and reviewing areas that require improvements.

2.10. Public water supply

Public water supply involves collecting groundwater and surface water and its treatment and preparation for various purposes such as drinking, food preparation, hygiene, community needs, and economic activities. This water is then transported and distributed from its source to the end user. With the rapid growth of the population, urbanization, environmental pollution, and the ongoing effects of climate change, ensuring and maintaining adequate drinking water is becoming increasingly challenging. According to a reference document from the European Commission, water is a precious natural resource that must be managed sustainably, and losses of this resource should always be minimized.

Organizations responsible for water supply must balance the efficiency of distribution networks with the effective use of natural, human, financial, and other resources while striving to meet the goals of sustainable operations. The water supply system consists of various structures, devices, and installations designed specifically for supplying water. This process includes collecting, treating, transporting, and distributing water intended for drinking, food preparation, hygiene, community needs, and economic activities, extending from the source to the consumer.

Water treatment refers to the processes aimed at controlling and improving water quality that do not meet the necessary standards. Water supply systems must ensure enough potable water that caters to the needs of consumers within their designated service areas. Depending on the area size, needs, and location of water sources and their yield, these systems can be categorized as communal or regional. Communal water supply systems serve individual communities where the distance to the water source is relatively short. Conversely, communities lacking adequate local drinking water sources may need to source it from farther locations through transport pipelines, which can span several tens of kilometers, resulting in regional water supply systems.

Water supply systems can also be classified based on the energy type used to maintain required water pressure, including gravitational, pressurized, or mixed systems. Gravitational systems leverage the potential energy of water sourced from higher elevations than the areas they serve. If this potential energy is inadequate, particularly for groundwater sources, a pressurized water supply system uses pumping stations to generate the necessary pressure. Overall, a water supply system comprises a collection of interrelated structures and equipment integrated into a cohesive system for facilitating the water supply process and includes the following water structures:

1. Water sources
2. Pumping stations
3. Facilities for conditioning, treating, or improving water quality
4. Water reservoir
5. Water supply networks

2.11. Sustainability of the public water supply system

According to a widely recognized definition, sustainability is "development that addresses the needs of the present without compromising the ability of future generations to fulfill their own needs." The sustainability of public water supply can be assessed through four key dimensions: social, economic, environmental, and technical.

Social Aspect of Sustainability: Water is a fundamental human necessity, alongside air and food, and the World Health Organization (WHO) has established guidelines to ensure drinking water quality. These guidelines primarily aim to safeguard public health. Access to adequate, safe, and accessible water is vital for life. Enhancing access to drinking water can lead to significant health improvements for the community, underscoring the need for rigorous efforts to maintain high drinking water quality standards.

When establishing mandatory limits, it is essential to incorporate these guidelines within the framework of local or national environmental, social, economic, and cultural contexts. Consequently, the social dimension of public water supply sustainability becomes a political matter, as everyone must have access to safe drinking water at a reasonable cost and in sufficient quantities tailored to the specific local or national environmental, social, economic, and cultural conditions. The availability of public water supply is defined by EU directives, which stipulate that.

Every settlement with over 50 inhabitants is required to be connected to the public water supply system by 2020. Challenges such as lack of access, high costs, insufficient water quantities, or poor water quality threaten the social sustainability of the public water supply. Regarding the economic aspect of sustainability, the guidelines set by the World Health Organization indicate that this is a political matter, just as much as the social side is. Water supply organizations must operate economically and efficiently, achieving long-term financial balance. In Europe, economic sustainability is guided by EU regulations like Directive 2000/60/EC and Directive 98/83/EC, which state that public water supply organizations should focus solely on public water supply activities, maintain independence, and ensure that their operations are cost-oriented rather than aimed at profit. The income generated from water sales must be sufficient to cover expenses related to energy, maintenance of water infrastructure, depreciation, and employee wages. Funding for the construction of water facilities is derived from water supply development fees (part of water pricing) and non-repayable grants from local government budgets and EU funds.

Focusing on the environmental aspect of sustainability, public water supply encompasses the extraction of groundwater and surface water, its treatment for drinking, food preparation, hygiene, and municipal use, as well as transport and distribution to end users. Water supply organizations must pay particular attention to safeguarding water sources to prevent adverse impacts. Protection measures against pollution, such as sanitary protection zones, must be established. The amount of extracted water must be regulated to ensure sustainable use of water sources, especially in service areas with limited water availability.

Lastly, the technical aspect of sustainability involves the complexities of water supply systems, which require adequate human resources (knowledge and skills) and material resources (machines, tools, and materials). Existing water supply systems have been in place for approximately 150 years and are aging, necessitating effective management and quality preventive and predictive maintenance, with corrective maintenance rare.

Water supply systems that incur high maintenance costs or necessitate frequent corrective actions need rehabilitation. Efficient management of these systems is essential. The elements of sustainability mentioned are interconnected; water losses in the public supply system hinder environmental sustainability and elevate the demand for water extraction. Excessive water extraction leads to increased energy and maintenance costs, adversely affecting the economic viability of operations and threatening economic sustainability. Inefficient systems result in disproportionately high-water prices, compromising social sustainability. Water supply organizations face the challenge of balancing the efficiency of distribution networks with the effective use of natural, human, financial, and other resources to meet sustainable business objectives. The surge in urban populations due to migration, growing trade, tourism, and other factors has resulted in overcrowded cities. These metropolitan areas are expanding more rapidly than anticipated, presenting a new challenge in supplying adequate drinking water to residents and industries. The authors explore the ecological challenges linked to drinking water supply in developing countries and analyze case studies of successful water supply organizations in Singapore and the Netherlands to identify their strategies for addressing public water supply issues.

2.12. Effectiveness of Public Water Supply Systems

The development of water supply systems has led to various methods and tools to enhance efficiency and minimize water losses, utilizing current scientific and technological advancements. However, outcomes often do not meet expectations as public water supply organizations struggle to embrace new knowledge, and changes are infrequently implemented consistently. According to a document from the European Commission, water is recognized as a vital natural resource that requires sustainable management, and efforts should be made to minimize any losses associated with it.

Water supply organizations must navigate the challenge of balancing the efficiency of distribution networks with the effective use of natural, human, financial, and other resources, as they bear the responsibility of achieving sustainable business objectives. With the rapid increase in population, urbanization, and the ongoing impacts of climate change, maintaining adequate water supplies for human consumption is becoming increasingly challenging. A publication from the World Health Organization emphasizes that water losses contribute to increased withdrawals and should be incorporated into a comprehensive long-term water resource management strategy. This is particularly crucial for regions with limited natural water resources, where ensuring adequate drinking water supply during drought conditions is difficult.

Significant water losses, are regarded as "waste," leading to perceptions of inefficiency in water supply organizations. Consequently, monitoring water losses is a key performance indicator for these organizations. Both the World Health Organization and the World Bank highlight that water leakage from distribution networks is a global issue that needs to be addressed.

Water supply systems face significant challenges, prompting all stakeholders to propose effective methodologies for reducing water losses and implementing these solutions in actual water supply systems. Water losses are critical factors affecting the efficiency and sustainability of public water supply, representing a global concern. They are widely recognized as essential indicators of the success of water supply operations.

In 1996, the International Water Association (IWA) initiated a working group focused on addressing water losses (WLTF) to standardize terminology and procedures for water accounting and establish consistent indicators for evaluating the managerial and financial efficiency of water supply systems. By the end of 2000, this working group had introduced concepts related to water loss balance, terminology, and efficiency indicators.

Water losses in public supply systems are typically defined as a percentage of the total volume of water introduced into the system (SIV). These losses can be categorized based on their causes. Recognizing the significance of this issue, the IWA has proposed a standardized water loss balance (WB), which relies on annual measurements, which were empirically found to be a suitable reference period. Each component of the water loss structure is measured in cubic meters per year (m^3/y), where 'y' signifies one year.

The annual volume of lost water, expressed as a percentage or in cubic meters, is a crucial indicator of water supply efficiency. Monitoring these annual losses over multiple years can reveal trends in efficiency. The components of the water balance include:

I. Captured water (Q)
II. Authorized consumption (QAC)

III. Billed authorized consumption (QBAC)
IV. Measured billed quantity of water (Revenue water)
V. Non-revenue billed quantity of water (N facilitated authorized consumption QUAC)
VI. Measured unbilled quantity of water
VII. Non-revenue water (QNRW)
VIII. Unmeasured unbilled quantity of water
IX. Water losses (QWL)
X. Apparent losses (QAL)
XI. Metering inaccuracies
XII. Unauthorized water consumption
XIII. Real losses (QRL)
XIV. Leaks in pipelines
XV. Bursts of pipelines
XVI. Overflowing reservoirs

High levels of water losses that are increasing indicate ineffective planning, construction practices, and inadequate predictive maintenance efforts. Water losses are inherent in all water supply systems. They can arise from operational and process-related issues or due to the degradation of essential functional properties of infrastructure over time, stemming from inadequate execution, poor maintenance, seismic events, construction impacts, and unauthorized use, among other factors. It is important to note that water losses are not static; they fluctuate both absolutely and relatively in response to various influencing parameters.

We differentiate between daily, weekly, and seasonal water consumption patterns and similarly categorize daily, weekly, and seasonal patterns of water loss. For instance, relative water losses tend to be highest when consumption levels are lowest at night. Conversely, relative losses decrease during the day when water usage increases. The extent of water losses related to their origins varies among different water supply systems, influenced by factors such as terrain topography, service area size, connection density, the age of water infrastructure, the types and properties of building materials, as well as the system's operational efficiency, management quality, and maintenance practices.

Water losses, denoted as QWL (Current et al.), represent the portion of the total water drawn, Q, in a one-year accounting period that escapes from the water supply network uncontrollably and unintentionally due to management and operational inefficiencies. The remainder of the supplied water that is delivered controlled and intentionally is referred to as authorized consumption, QAC (Authorized Consumption). To conduct a thorough and objective analysis of the water supply system’s status, various indicators that form part of the standard IWA water loss balance must be considered.

Factors such as climate change, population growth, and the deterioration of infrastructure continually pressure water supply organizations to minimize water losses. There is increasing recognition of the necessity for precise assessment and effective management of water losses to conserve water resources. Leakage within the distribution system adversely impacts many waters supply system operational aspects. Excessive leakage raises the overall water pumping, treatment, and distribution costs, thereby increasing energy demands. To offset the volume of lost water, the capacities of water supply facilities may be unnecessarily expanded.

According to the International Water Association (IWA), CARL (Current et al.) 's annual actual losses cannot be entirely eradicated. A certain level of leakage will always exist within any system, which must be tolerated and managed within acceptable thresholds. The challenge lies in the optimal management of water losses. Reducing these losses is a critical endeavor that...

Maintaining effective water supply processes demands ongoing attention and action from all stakeholders. Over time, the acceptable level of water losses referred to as CARL is periodically reassessed based on evolving knowledge, technological advancements, and sustainable business objectives. CARL reflects the currently accepted standard for water losses. In their article, Vermersch and Rizzo discuss the formulation of an effective action plan and highlight the substantial efforts made by many organizations, including the IWA, to introduce innovative concepts and practices aimed at enhancing efficiency in water supply management, particularly in minimizing non-revenue water (NRW). They note that NRW remains largely uncontrolled globally within most water supply entities. Despite significant investments to mitigate NRW, outcomes often fall short as levels rise in seemingly unavoidable manners. This indicates that merely refining definitions and concepts is insufficient; a thorough investigation into the root causes of failures during the planning and execution phases is essential, warranting a more systematic approach.

Drawing from their extensive experience implementing various action plans to curtail NRW, the authors have developed a practical framework for such planning. A strategic and proactive approach customized to the specific needs of each water supply organization is vital for enhancing the efficiency of public water services. Conversely, a passive approach or disregard for critical factors impacting water loss control will inevitably lead to escalating losses and detrimental effects. Establishing a structured framework, implementing necessary actions, and monitoring progress through suitable indicators are crucial to reversing this trend and halting the ongoing rise in water losses. Vermersch and Rizzo, as part of the WLTF working group, emphasize the importance of altering the management strategies of water supply organizations, which they identify as the 'missing link.' Their work, published in 2009 and expanded in 2016, stresses the need for a successful action plan to achieve sustainable results.

They conclude that managing water losses is effective only when integrated into a comprehensive, sustainable strategy. Their insights suggest that reducing non-revenue water extends beyond engineering challenges, intersecting with social sciences and managerial competencies. They advocate for a three-dimensional action planning structure while introducing novel management tools such as network culture analysis, stakeholder networks, and change kaleidoscopes. They assert that 'change' is pivotal, and when effectively managed, it leads to achieving targeted goals. Ultimately, they highlight that the cornerstone of a successful water supply organization lies in proactive and authoritative management of all operational facets. Continuous improvement necessitates effective problem-solving through a structured methodology, making it imperative to adapt behavior patterns and leverage the latest knowledge and advancements in these efforts.

The proposed model must incorporate new management knowledge for successful implementation and effectiveness in water supply systems to minimize water losses and achieve optimal recovery. A general invitation has been extended to stakeholders in water supply systems to suggest effective methodologies for diminishing water losses and apply these approaches in real-world contexts. Water supply organizations must navigate the challenge of balancing the efficiency of distribution networks with the effective use of natural, human, financial, and other resources while striving to meet sustainable business goals.

As water supply systems grow larger and older, they become increasingly complex to monitor, manage, and maintain. This situation has led to a persistent rise in negative performance indicators, such as the ongoing increase in non-revenue water (NRW). Changing monitoring, managing, and maintaining practices in water supply systems has become essential to enhance efficiency and improve key business indicators.

Key Performance Indicators (KPIs) for public water supply are crucial for business reporting. They provide stakeholders, users, the public, non-governmental organizations, and regulators with clear insights into the effectiveness of the public water supply system. These performance indicators focus on several key areas, including environmental impact, resource efficiency, cost-effectiveness, and water loss within the supply system.

The most frequently employed performance indicators pertain to water losses, as these directly or indirectly influence all other indicators. Unfortunately, traditional performance indicators that fail to enable efficiency comparisons between public water supply organizations—domestically or internationally—are still in use.

Water losses in the supply system expressed as a percentage of water drawn over a year, serve as a primary performance indicator for water supply organizations; however, this measure alone is inadequate for assessing absolute efficiency. Berg and Padowski analyze the theoretical aspects of benchmarking among water supply organizations, underscoring its significance for developing and implementing water policy.

Benchmarking allows regulators and municipal organization managers to assess performance over time across different water supply companies and among various countries. As a result, it can act as a catalyst for improved management practices within these organizations. Benchmarking may also help resolve disputes by encouraging collaboration between technical researchers and those studying efficiency for government agencies and water supply companies, addressing the broad range of issues that arise during performance assessments.

Water utility analysts have developed five methodologies for comparison, each focusing on specific issues. Moreover, if managers lack knowledge about how well their organization or sector performs, they cannot establish realistic goals for future planning. The evaluation process is divided into five steps: identifying objectives, selecting methodology, collecting data, reviewing and analyzing data, and testing for consistency and sensitivity. They stress that comprehensive indicators should be utilized during evaluation, as relying on partial data can lead to inaccurate assessments. A standard measure of water losses is the ratio of total losses (both apparent and actual) to the total water drawn over a year, expressed as a percentage. However, this measure alone is inadequate for thoroughly evaluating a water supply system's effectiveness. For instance, comparing different water supply systems solely based on this metric does not yield an accurate understanding of their efficiency. This is due to the complexity and diversity of water supply systems, each with unique characteristics. The American Water Works Association recommends additional performance indicators to enhance the water supply system management assessment. These indicators, originating from English-speaking regions, include unbilled water, Public Water Supply NRW, water losses WL, real water losses RL, actual annual water losses CARL, unavoidable yearly real losses UARL, and the Infrastructure Leakage Index (ILI), which is defined by the formula: ILI = CARL / UARL.

2.13. Actual water losses in water supply systems

Actual water losses occur in all water supply systems, primarily due to poor connections and breaks in the network and other water structures. These issues arise from the degradation of essential functional properties in system components caused by aging, substandard construction, inadequate maintenance, ground seismic activity, and direct and indirect effects of nearby construction work. As the network ages, the frequency of failures tends to increase. Failures can be categorized as stationery or growing; the latter progressively worsen over time, leading to pipe bursts that necessitate repairs. A failure initiated by a pipe burst is illustrated in Figure 2.5. When a pipeline loses its functional properties, it is referred to as a pipe burst or break. Such bursts result in substantial indirect damage due to the destruction and flooding at the site caused by the rapid release of a large volume of water. At this stage, failures are typically easy to observe, making their consequences visible to experts and laypersons, leading to emergency corrective measures in the affected area of the water supply network. Timely identifying these failures poses significant challenges for water supply system operators, necessitating a proactive management and maintenance approach. Given that a large portion of the water supply network is situated underground, dynamic changes and the emergence of new failures or water leaks often remain hidden, eluding detection by direct observation. Effective detection demands a systematic approach employing suitable technology, comprehensive knowledge, and experience to uncover these 'invisible' failures.

I can go unnoticed for months or even years. As a result, water leaks in defective areas can linger for an extended period, leading to significant water losses and considerable indirect damage from the cumulative effects of the lost water. In severe cases, prolonged water leakage may result in substantial damage to surrounding buildings and high indirect costs to address the ensuing damage. Figure 2.6 illustrates the consequences of a failure discovered only after soil collapse and damage to nearby structures occurred.

Effective management and maintenance of the water supply system necessitate process management activities where parameters fluctuate in space and time. Failures can originate anywhere within the supply area’s water network. Since much of the water supply infrastructure (such as pipelines and valve chambers) is underground, identifying faulty areas requires a continuous and systematic approach requiring significant human and material resources and advanced technologies.

As the water supply system expands, the challenges become more pronounced. Ongoing efforts to enhance public water supply efficiency require developing and applying new analytical methods to meet strategic, tactical, and operational objectives. The techniques employed in this process influence numerous system parameters, interconnections of which can be highly complex, making statistical methods particularly useful. This allows findings and analyses from a specific portion of the water supply system to be generalized to the entire or even other water supply systems.

The author presents an example of employing the "Monte Carlo" statistical method for effective loss management in the water supply network. Iličić notes that loss management approaches are often limited to a series of fundamental actions lasting from several days to, in extreme situations, even weeks. He emphasizes that enhancements in loss detection systems should focus on:

Identifying and localizing pipeline bursts within the distribution system,
Distinguishing between pipeline bursts and unexpected consumption or systemic issues,
Differentiating sudden bursts from those that develop gradually.

To improve processes aimed at these goals, exploring new methods for detecting and localizing pipeline bursts and refining existing ones is essential. Opportunities for advancement are growing with constant developments in computer technology. The author investigates using neural networks to detect and pinpoint bursts under varying water leakage intensities. By analyzing flow and pressure data collected from designated locations, the study examines the potential to identify a pipe burst within a controlled area and locate the exact spot of uncontrolled leakage.

To effectively recognize and apply these connections, it is crucial to establish enough measurement points for flow and pressure monitoring. The WLTF group is devising a strategy to tackle the challenge of efficient water loss management and suggests four key action directions: a water loss control strategy - actionable measures; Actual water losses CARL can be diminished by implementing interventions at any of them.

Four independent action directions have been proposed. The Public Water Supply Group WLTF has introduced a new indicator called 'Economic Level of Losses' (ELL). Water supply organizations aim to reach this economic level, as further investments in rehabilitating water supply infrastructure can lead to substantial expenses with minimal impact. Excessive costs could upset the social and economic sustainability balance within the water supply system.

The second action direction, pressure management, aims to proactively delay or avert failures. Elevated static and dynamic pressure in the water supply systems is a significant cause of failures. The static pressure at the connection point is determined by the dimensions of elevation zones (hydraulic gradient line) and the height of the water supply connection within those zones. Dynamic pressures in the water supply system depend on consumption patterns and management methods. Failures may occur when static pressure is high, for instance, at night when consumption is low and water tanks are full (resulting in the highest hydraulic gradient), or during periods of high dynamic pressure (such as hydraulic shocks). Pressure management is accomplished by adjusting the water level in tanks, optimizing pumping station operations, and utilizing remotely controlled pressure regulators at critical points in the system.

The third action direction, 'infrastructure management,' aims to standardize water flow, quality, and pressure distribution throughout the supply system. Certain water supply systems, such as Berlin's, have water tanks solely at the start of their networks, relying on active management of pumping stations and infrastructure management for pressure and flow control.

The fourth action direction is 'speed and quality of infrastructure rehabilitation.' Rehabilitation efforts fall under the category of investment maintenance. Comprehensive and high-quality infrastructure renewal will yield the best long-term outcomes in mitigating water losses. Optimally, results can be attained by employing advanced materials (considering their performance and longevity) and contemporary construction techniques for water supply systems when replacing outdated components. However, this direction is often applied only partially due to economic constraints (high costs) and organizational challenges (working in active urban areas). According to WLTF recommendations, 0.5% to 3% of the water supply system should be reconstructed annually to ensure technical sustainability. Additionally, the Public Water Supply Group WLTF proposes dividing the water supply system into smaller, manageable zones known as District Metered Areas (DMAs), the theoretical and practical implications of which are assessed using the DMA methodology.

Managing DMA zones is only effective when integrated into a comprehensive and sustainable mix of measures guided by a long-term strategy focused on actively monitoring, reducing, and controlling water leakage in the supply network. While striving for optimal results in minimizing water losses, the anticipated achievements are often insufficient. The authors note that a significant challenge is the lack of understanding and planning for long-term activities. They outline why reducing water leakage in supply systems is crucial and propose methods to tackle water loss issues using available technologies, aiming for a balanced approach that considers all aspects of sustainability within the water supply organization.

Westphal et al. emphasize recent advancements in computer technology and modeling, along with the availability of real-time hydro-climatic data. Our improved capability to create user-specific graphical model interfaces has spurred considerable development and use of Decision Support Systems (DSS) for water resource management. They reference Boston as an example, where the city has implemented and continues to enhance adaptable real-time water storage management to ensure sufficient drinking water supplies. The DSS connects watershed models, hydraulic reservoir models, and water quality models within the reservoir using both linear and nonlinear optimization algorithms.

Highlight the sustainability challenges facing water supply systems, including increased water losses due to more frequent breaks in the network, decreased drinking water resources, uncertainty surrounding the structure of non-revenue water (NRW) consumption, and rising water demand. They discuss water supply network management, underlining the benefits of employing sensors in these networks to gather valuable data on stress, temperature, pressure, flow, and corrosion. The authors stress the significance of assessing the condition of water supply pipes to plan preventive maintenance effectively. They also present various indicators that can be used to evaluate the condition of these pipes.

2.14. DMA Zone

Water losses inherent in all water supply systems necessitate public suppliers or distributors to proactively manage these losses. A strategy is developed based on the system's specific characteristics, leading to the selection of the most suitable method. The Water Loss Task Force (WLTF) group advocated for the zoning method by introducing District Metered Areas (DMAs). This approach gained significance in the mid-20th century amidst the rapid expansion of water supply systems. The core concept of this method involves segmenting the water distribution system into a manageable number of smaller subsystems, referred to as controlled zones, to facilitate monitoring and management. Specific criteria must be fulfilled to establish a DMA zone, particularly the condition...

Accurate measurement of the water entering and exiting the DMA zone is essential. The disparity between the volume of water that flows into the DMA zone and the volume supplied to end-users as revenue water (RW) is termed non-revenue water (NRW). The majority of NRW is attributed to actual water losses. Smaller public water supply systems may have a single DMA zone, whereas significantly larger systems may have dozens or over a hundred DMA zones.

We evaluate water losses, quality, and efficiency of the water supply system categorized by DMA zones by comparing the quality across different zones. The measurements and analyses performed in DMA zones aim to pinpoint problematic areas for planning and undertaking necessary actions related to monitoring, managing, maintaining, or rehabilitating water supply infrastructure, as well as establishing priorities and timelines for these activities. This effort aims to identify failures within the DMA zone early, particularly before pipeline bursts, allowing for proactive measures.

Once a potentially significant failure area is identified within the DMA zone—typically within a few hundred meters—efforts to locate the failure accurately for remediation are initiated. Specialized personnel utilize advanced equipment to pinpoint the exact failure site within the identified area. To maintain the sustainability of DMA zones and, by extension, the overall water supply system, it is crucial to establish DMA zones based on predefined guidelines while considering various influencing factors.

Forming and managing DMA zones is a critical strategy for controlling water losses, and it should not be approached as a quick fix. It represents a long-term commitment that can effectively mitigate water losses when implemented correctly and comprehensively. Managing DMA zones is a proven approach that aids in monitoring and reducing unregulated water leaks from the distribution network. However, reliance on traditional metrics generated solely through staff observations significantly restricts its effectiveness. Consequently, failures can remain undetected for long periods, leading to substantial direct and indirect consequences.

Each DMA zone encompasses several thousand end-users, making continuous water meter readings impractical. Furthermore, the issue of simultaneity in reading arises, as water consumption is typically recorded monthly or every few months. In the interim, consumption levels are estimated for billing purposes. These limitations impede the analysis of flow and consumption within the DMA zone, rendering it less practical for early water leakage detection.

2.15. Legislative framework

National laws, European Union directives, and other subordinate legal acts govern the regulation of public water supply operations in the Republic of Croatia. "Water services" encompass public water supply and public drainage services. Water service providers are legal entities authorized to deliver these public services. As stipulated by the Water Act, all providers must be organized as trading companies or public institutions dedicated solely to providing drinking water and wastewater drainage since the start of 2012. The founders and owners of these providers can only be local government units, such as cities and municipalities.

If community service providers previously engaged in other drinking water supply, drainage, and wastewater treatment activities, they were required to separate those activities from their operations within three years of the Water Act's effect, specifically by early 2013. Water service providers operate within defined water supply areas and manage wastewater drainage in designated agglomerations. A service area consists of one or more water supply zones and agglomerations.

In alignment with the Water Management Strategy and the Water Act ('Narodne novine,' numbers 153/09, 63/11, 130/11, 56/13, and 14/14), an independent regulatory body, the "Council for Water Services," was established to oversee the legality of water service pricing and the fees for development under the Financing of Water Management Act ('Narodne novine', numbers 153/09, 90/11, 56/13, 154/14, 119/15, 120/16, and 127/17).

Public water supply is crucial for the European Union, and the operational frameworks are increasingly detailed. This sector is vital for public interest, essential for citizens' daily lives in Croatia, and necessary for environmental protection, highlighting the complexity of regulations in this area. Consequently, adopting a specific law to govern water services became required. In late 2018, the "Water Services Act" was proposed for public consultation. With its adoption, the regulation of water services will transition from the previous framework established under the "Water Act" ('Narodne novine', 153/09, 63/11, 130/11, 56/13, 14/14, and 46/18).

Chapter III:
METHODOLOGY

3.1. Overview of the Research Problem

The efficiency and sustainability of public water supply systems are pressing global issues, with water losses being a critical concern. To address this, I will examine relevant scientific databases and compile available literature focused on enhancing water supply organizations' efficiency, economic viability, environmental stewardship, and social sustainability. I will outline the essential characteristics of this activity and pinpoint critical challenges that impact on the efficiency of public water supply systems.

The findings from the literature review will help identify commonly used key performance indicators (KPIs) and various types of losses that occur through the utilization of natural, human, financial, and material resources by water supply organizations. By analyzing the insights and examples from the collected literature, I will assess activities that significantly enhance the efficiency of these organizations.

Additionally, I will evaluate potential legal constraints, including European Union directives and Croatian laws, that may influence future improvements in the public water supply process. Following this, I will explore how emerging knowledge, information, and communication technologies (ICT) related to business process digitalization can be applied, specifically within water supply organizations.

The data gathered during the literature review will also facilitate an analysis of water supply processes amenable to digitalization and aid in developing an integrated public water supply management model. Drawing from my analysis and the identified inefficiencies in the water supply process, I will create a unique model to enhance the efficiency of water supply organizations, incorporating tools for measuring effectiveness.

The establishment of an effective remote meter reading system, integrated with the billing information system (UPN1), has been developed and implemented by the Water Supply and Drainage Branch (now Water Supply and Drainage Ltd.) under the name AWMR, which stands for Automatic Water Meter Reading (smart grid). This initiative is primarily driven by legal regulations, such as the Law on Efficient Energy Use in Direct Consumption (NN 55/12 Art. 13), the Consumer Protection Act (NN 79/07 Art. 24), Directive 2010/31/EU on the Energy Performance of Buildings, and the Water Act (NN 153/09). Additionally, customer demand for an accurate, transparent, and reliable water billing system based on actual consumption plays a significant role. This demand is particularly highlighted in older buildings without internal water meters, where water billing often relies on estimating consumption based on the number of residents.

Remote reading via the AWMR network is crucial for creating a technical information system to reduce losses in the water supply network. This system needs to be implemented across approximately 3,000 km of pipelines in the City of Zagreb, utilizing modern ICT solutions, including hydraulic modeling systems, geographical information systems (GIS), leakage management systems (WLM), telemetry, and remote reading of smart water meters.

The City of Zagreb and its surrounding areas (Stupnik et al.) form a service area managed by Zagreb Holding - Water Supply and Drainage Branch, which serves over 190,000 water meters and approximately 370,000 customers. These figures underscore the complexity of the reading system, with a significant portion of readings currently conducted manually using traditional methods. This results in inadequate frequency and accuracy, leading to estimations in some cases and customer dissatisfaction due to incorrect billing.

About a decade ago, the implementation of remote reading via local M-Bus networks began, primarily in newly constructed buildings, in compliance with legal mandates for secondary water meters. Initially, this technology employed wired busbars according to the EN 13757 standard, but more recently, wireless M-Bus systems (EN 13757-4:2005; 2012) have been utilized. In the City of Zagreb service area, M-Bus has been installed at over 44,000 measuring points, but only around 6,500 points (approximately 15%) are currently capable of successful remote readings. This limited success stems mainly from malfunctions and insufficient maintenance, which fall under the responsibility of building owners or residents.

For old buildings, external companies contracted by building owners have installed internal water meters for reading and billing. This has resulted in numerous small systems for reading and billing, amounting to about 1,300 measuring points. Customers pay for these services as a separate charge despite them being part of the overall VIO service.

Developing these systems and employing various often non-standard technical solutions has been sluggish. The installation figures illustrate this over the past decade, where less than 1% of potential internal water meters have been installed in older buildings. To significantly enhance remote reading, the VIO Branch began actively developing a comprehensive and systematic solution in early 2012. This initiative aims for a streamlined advanced network for the remote reading and billing of water in the City of Zagreb, initiated through several pilot projects led by the VIO development team.

Projects have played a crucial role in discovering optimal solutions outlined in this study. Several successful pilot projects were implemented in 2012 and 2013. The first pilot occurred on the Knežija – Jarun route, where impulse water meters with registrars were installed in water measurement shafts. The second pilot was conducted in an old residential building at Prilaz Slave Raškaj No. 9, which involved installing a new main ultrasonic water meter and impulse (HRI) valve water meters in 12 apartments. Registrars and signal concentrators connected these to the remote network and billing system VIO. The third pilot was implemented at locations affiliated with Zagreb Holding subsidiaries, VIO, and Čistoća. The Pilot project – Mamutica, the largest residential building in Zagreb and Croatia with over 5,500 apartments, is in progress. The installation of new central water meters commenced at the end of 2013 and is being integrated into the AWMR telecommunications network. This building will begin a series of implementations of new OTU3 systems.

The most modern and advanced ICT solutions have been utilized throughout these pilot projects. The concept of an advanced remote network for reading water meters (AWMR) is founded on connecting radio water meters to local network concentrators (e.g., buildings or individual city districts) and linking them to a remote wireless (WAN) network via proprietary access points (AP). ZigBee technology, by the IEEE 802.15.4 standard, was used for linking water meters within local networks (WLAN, WPAN, HAN), along with the standard M-BUS technology for reading water meters (Wireless M-BUS, EN 13757-4; OMS). The remote network (WAN) utilizes ULP technology (ON-Ramp), demonstrated to be effective for reliable, long-range data transmission at low power levels in the ISM unlicensed radio frequency band (tested for a range of approximately 15 km at 500 mW and 2.4 GHz). In addition to this primary remote system, the AWMR network is adaptable to incorporate other available technologies, accepting various wireless, wired, and optical systems through its concentrators, such as GSM/GPRS, SDM (fiber optic distribution), and Ethernet.

Significant attention in the study has been dedicated to analyzing and selecting suitable water meters compatible with the AWMR network. A key reason for this focus is the previously mentioned factors influencing project costs, alongside the necessity for a solution that is accurate, reliable, and cost-effective for the new network infrastructure. The review of existing impulse water meters, particularly those utilizing impulse output via reed contacts, revealed unreliability and poor accuracy in measuring water consumption. Furthermore, traditional water meters with impulse output require a registrar. This additional device converts electrical impulses from the meters into radio signals for reading through concentrators in the AWMR network.

As a result, a more reliable and cost-efficient solution was pursued. The selection of new ultrasonic (UZV) and electromagnetic (EM) water meters featuring integrated radio modules successfully met the specified requirements, particularly for internal and secondary water meters. Significant advancements have also been made in customer communication through the development of the AWMR network, which provides advanced services via the Internet that were previously unavailable. In this context, the introduction of the MY VIO customer internet portal, which connects to AWMR, is noteworthy.

The network, integrated with a billing system, allows customers to monitor their water meter status, receive alerts for malfunctions, track debt claims, access e-invoices, and make payments through electronic slips. Future advancements may include developing sophisticated mobile applications with MOJ VIO functionalities compatible with smartphones. This progress is facilitated by the bidirectional communication of the AWMR network, the central MARS system (Measurement and Automated Reading System), and the billing system linked to an e-UPN database.

Since the inception of the AWMR network, there has been continuous and often immediate communication with customers to enhance the understanding of water meter readings and the integration of the billing system. This feedback led to establishing a new Mixed Water Billing System, developed within the UPN billing framework, which addresses the issue of obtaining residents' consent for installing internal water meters. Historically, from 2006 to the present, 100% consent from residents was mandated for such installations.

In cases with a mixed billing system (where part of the building has internal meters and part is billed based on residency), the consumption difference – defined as the gap between the total readings from the main water meter and the sum of internal meters – was allocated to residents without internal meters based on the standard consumption ratio (UZP) determined by their apartment size. This Δ also accounted for losses from internal systems, necessitating consent from residents, particularly those without meters, to adopt this billing method that included these losses.

Resolving the mixed water billing challenges in older buildings became crucial during the AWMR development process, as it was recognized that a solution was necessary to encourage residents to install water meters. Introducing the new Mixed Water Billing System, detailed in Chapter 10.3 of this study, eliminated the need for residents' consent. This system directly links water consumption measurement and billing to actual usage, resulting in a more equitable and precise approach than previously available.

We anticipate that the costs associated with installing water meters and the revised billing system will significantly facilitate the expansion of the AWMR network concerning internal meter installations in older buildings. The AWMR network offers substantial enhancements in monitoring water usage and evaluating the accuracy of internal installations, fostering conditions that support increased energy efficiency in consumption, particularly in older structures (in line with Directive 2010/31/EU). According to UNDP data, unnecessary water consumption can be reduced by as much as 40%, corresponding to a similar decrease in electrical energy required for water lifting [specific factor; kWh/m3]. Our projections, informed by experiences from pilot initiatives, indicate that residents could experience considerable advantages following the installation of internal water meters and their integration with the AWMR into older buildings.

The AWMR network can reduce water consumption by up to 30%. Beyond the substantial benefits that customers will experience, a primary advantage of the AWMR network lies in its potential to minimize losses within the water supply infrastructure. Utilizing a technical information system designed to mitigate water losses, optimizing the supply network hinges on precise real-time consumption measurements, which the AWMR network facilitates through its robust connection to the GIS system. We anticipate that the current losses in the network, approximately 48%, will decline soon, thanks to the AWMR technology implemented in newly launched loss reduction projects (Team 200, Team 5M).

The establishment of zones dedicated to identifying and monitoring water losses (DMA), along with integrating the GIS with the billing system (UPN) and the AWMR network, will enable the development and optimization of the hydraulic model (HM) and initiate systematic measures for reducing actual water losses (QRL). In this regard, Chapter 12 outlines the cumulative savings from reduced water losses, amounting to approximately 187 million m^3 of water or energy savings of around 84 GWh. Based on the planned implementation of AWMR and DMA zones, the tangible benefits of investment are anticipated to be recognized by 2015. The objective is to diminish water losses from 48% to 30% by 2020, nearing the maximum reduction potential.

By implementing new General and Technical Conditions for water service provision [12] and developing the AWMR network, past shortcomings in maintaining the accuracy of internal water meters are being addressed. Under the previous General and Technical Conditions of 2006 (Article 78), customers, as owners, were accountable for the upkeep of their internal meters. As per the billing framework, these meters served a control function for water distribution. With the introduction of the Mixed Water Billing System, crafted as part of the AWMR network and the new automatic billing system (UPN), internal water meters are now recognized as legal measuring devices that accurately assess actual water consumption for billing purposes, thus aligning with the Measurement Act [42]. This unification negates the distinction between maintenance responsibilities and ownership; all meters, including internal ones, are now under the purview of the water service provider (General and Technical Conditions for the Supply of Water Services [12]; p. 21, Article 34.), which assumes responsibility for their maintenance. Consequently, significant enhancements have been achieved regarding the accuracy and reliability of the entire reading system, relieving customers of financial obligations related to calibration.

In conclusion, establishing the AWMR network will significantly enhance the overall water supply infrastructure (distribution network) and the internal consumption network. Such improvements are poised to yield substantial financial savings, particularly for the European Union's energy objectives (EU 20-20-20, which include a 20% increase in energy efficiency, a 20% reduction in greenhouse gas emissions, and a 20% uptick in the share of renewable energy sources). Moreover, the AWMR network is fully compatible with the Digital Agenda6 concerning the integration of ICT.

The sector involving public institutions and the effects of intelligent grids on enhancing energy efficiency in buildings plays a crucial role. Currently, the Zagreb water supply system operates 8 out of 38 water wells, providing an overall capacity of approximately 4,500 liters per second, or 390,000 cubic meters per day, sufficiently meeting the city's water demands. The primary water wells serving Zagreb include Mala Mlaka, Velika Gorica, Petruševec, Sašnak, Strmec, Zaprude, Žitnjak II, and Bregana, alongside the significant capture system at Slapnica.

In conjunction with the modernization and expansion of the water supply infrastructure, a key priority is safeguarding the remaining drinking water reserves in the Sava aquifer and preventing potential contamination of the wells. Given the geographical layout surrounding Zagreb, the water supply system is stratified into three zones based on elevation: Zone I at 185.50 meters above sea level, Zone II at 264.50 meters above sea level, and Zone III at 344.00 meters above sea level. Water reservoirs are positioned at the upper boundary of each zone, totaling 17 reservoirs with a combined volume of 114,560 cubic meters.

The Zagreb water supply system spans approximately 70 kilometers, stretching from the Slovenian border in the west to the town of Vrbovec in the east, with northern limits at Sljeme and southern at Kupinečki Kraljevac, covering an area of about 800 square kilometers. It comprises around 2,635 kilometers of water supply pipelines featuring various ages, materials, and diameters (ranging from 50 to 1100 mm). This network has approximately 9,000 valve chambers, 26,167 hydrants, and roughly 92,200 connections. This comprehensive system serves around 850,000 residents.

Water extraction occurs at eight intakes, consisting of five wells in Zagreb, one well in Velika Gorica, and another intake site in Samobor, complemented by a capture system. The identified water wells are Mala Mlaka (10 wells), Velika Gorica (3 wells), Petruševec (8 wells), Sašnak (6 wells, 3 of which are pumped), Zapruđe (3 wells), Žitnjak II (1 well), Strmec (5 wells), and the Slapnica-Lipovec capture system.

3.2. Research Problem and Questions

Today, VIO supports several billing systems through various IT applications. Some applications, like RISOV and RINUS, are implemented within the Branch. In contrast, others are implemented externally, such as ISNPV (company APIS) and various smaller billing systems for apartments with internal water meters. The total number of invoices generated from these systems for the City of Zagreb, Samobor, and Sveta Nedelja exceeds 380,000.

The billing system RISOV (Computer et al. of Water Supply) is built on the old Oracle 8 relational database and the UnixWare operating system. Initially developed by Infosistem in 1989, the system is now under the full support and continuous improvement of VIO developers. These developers are responsible for maintaining and enhancing the system, using software tools such as Oracle Report 2.0, Oracle Forms 3.0, ProC, SQL, and PLSQL.

The RISOV billing system consists of the following modules:

I. Master database
II. Water meter reading
III. Preparation for invoicing
IV. Conti balance and billing
V. Depression
VI. Insights and reporting at all levels
VII. Data archiving

Part of the mentioned modules are no longer used today, and part is used in a modified form because they have undergone a series of updates due to internal needs and legal obligations in the last 24 years that the application has been in the Feasibility Study AWMR-VIO function. During that period, the application migrated several times to various relational databases, starting with Oracle 5, 6, 7, and up to today's version 8.

The RISOV system is a comprehensive tool designed to manage master data on public water supply and drainage services users. It calculates and invoices water consumption and all other fees based on the calculation of water used and provided drainage services. In addition to water supply and drainage services, the system also handles the following:

I. compensation for water protection,
II. fee for water use,
III. fee for water development,
IV. drainage development fee,
V. wastewater treatment service,
VI. and the corresponding value-added tax.

Calculations from RISOV are carried out for over 175,000 metering points in the City of Zagreb area, and invoices from this system are delivered to over 160,000 customers.

The calculation algorithm in the RISOV system is intricately linked to the variable and fixed part of the price of the VIO service. The variable part accounts for the difference in water consumption, expressed in m3, as indicated by the water meters, between the previous and new readings. Since not all water meters can be read every month, estimates are often used for calculation. There are several types of calculations involved in this process, each serving a specific purpose:

I. Calculation according to the water used according to the reading of the central water meters (GV),

II. calculation according to the water used according to the reading of the secondary water meters (SV),
III. Calculation according to attrition - the percentage in which an individual user participates in total consumption,
IV. calculation according to the reported consumption of internal water meters with the included share in the everyday consumption (consumption difference factor Δ),
V. calculation according to the number of people (performed by APIS based on the consumption measured at the central water meters).

The calculation respects several additional characteristics of individual users, such as several types of privileges belonging to a social category of citizens, territorial affiliation, and other characteristics that affect the price or method of calculation. As already emphasized, part of the water meter fails to be read every month (according to Table 1 2-1, the average number of readings amounts to slightly over three readings per measuring point per year), which is why the RISOV system uses an algorithm for estimations. According to this algorithm, assessments are carried out for the previous two years, when possible, i.e., for cases where significant water consumption oscillations are unknown (such as cracks and significant failures in internal installation). If it is not possible to apply the system assessment for assessment are

Appropriate shorter periods are taken, or assessments are carried out personally by Sales Service representatives (smaller percentage of evaluations). The RISOV system is used to the greatest extent by all departments of the Sales Department and the Accounting and Finance Department to update data daily, as well as all other departments to obtain the information needed in the performance of daily tasks.

Within the Sales Service, the RINUS system is used by:

I. The department sells connections and services (mainly to obtain information during transmission to new users).
I. Water sales department (for updating master data on users, for the needs of reading water meters, implementation of all preparatory work for invoicing purposes, implementation of the invoicing process, and for the needs reporting).
II. Collection department (for issuing warnings before exclusion, orders for exclusion, records exclusion from the public water supply system due to debts).
III. The sales promotion department (to obtain information about legal users to disclose illegal connections).
IV. Customer Relations Department (for obtaining all available information to provide quality information to end users)

With the introduction of the new billing system, the UPN RISOV system will stop being used. In addition to the RISOV billing system, the VIO Subsidiary also uses the RINUS billing system. This system is like RISOV's old database version under Oracle 8 and the UnixWare operating system. The program tools VIO developers use when upgrading and maintaining this system are Oracle Report 2.0, Oracle Forms 3.0, ProC, Sql, and PLSql.

The system was initially built and put into production in 1989. At that time, it was used for the entire bookkeeping area. It included modules: bookkeeping material, invoicing of services, account balances of customers and suppliers, bookkeeping of fixed assets, and general ledger. Today, this system is used exclusively for keeping register records and accounting for:

I. users of rented hydrant extensions,
II. users of drinking water supply tanks,
III. calculation of technological water consumption,
IV. consumption calculation for illegally connected users.

The calculation is based on the consumption of water measured in m3 with the application of appropriate, valid prices. In addition, the algorithm for hydrant extensions also calculates the number of days the rented extension will last. In addition to water supply and drainage services, the following charges are also calculated for:

I. protect water,
II. water use,
III. water development,
IV. drainage development,

and on the wastewater treatment service and the corresponding value-added tax. Employees of the Sales Department use the system RINUS to invoice all the services mentioned above, Finance and Accounting Department employees to record and update payments, and everyone else who needs information from this system. The RINUS system is used for a total of about 300 users.

The ISNPV billing system is implemented by the company APIS based on the data submitted by the VIO Branch every month. This system was introduced in the early nineties of the last century based on the decision of the City of Zagreb published in the Official Gazette of the City of Zagreb. The system is intended for water calculation and issuing invoices for apartments in buildings that do not have an internal water meter but have a central water meter that measures the total consumption of the building (one entrance). The calculation is based on the distribution of consumption according to the number of household members. The calculation is first carried out in the RISOV system, after which the invoice (file) for each building is submitted to APIS, which takes the calculation into its database and performs the final calculation according to the number of household members (apartment) and turns out to account for customers.

This billing system also includes keeping data on payments by user's debts, complete bookkeeping, a salad of customer accounts, and a module for issuing warnings before lawsuits and complaints. In the ISNPV-APIS system, the calculation is carried out for the category of residential building buyers with one standard water meter. With the introduction of JUP, a smaller number of private houses and apartments with separate water meters were switched to this system. The total number of users who receive a monthly invoice from the APIS system is 209,222 (Sales Service data for five months of 2013)

The KOMISI/ISD billing system was implemented at the VIO location in Samobor. This system is based on Oracle Fusion Middleware 11g and Apex 4.1. As part of the functionality in use are:

Communal accounting,
Financial accounting,
Customer account balances,
URA/IRA and VAT accounting,
Material and goods bookkeeping,
Ordered record,
Posting of payments and statements,
Interest calculation,
Standing orders,
Book of malfunctions,
System administration.

The total number of users in Samobor and Sveta Nedelja who receive a monthly invoice from the KOMIS/ISD is 18,075 (data from the Sales Department for Samobor, May 5, 2013)

According to data from the VIO database for March 2013, 175,336 water meters were installed in the City of Zagreb service area. Among this number, the highest percentage of water meters (GV) were installed for family houses (56.5%), followed by secondary (SV) water meters for new buildings (26.1%), central water meters in buildings (9.2%), and GV for industries (7.3%), while the least number of water meters were installed in apartments of old buildings (existing internal water meters account for only 0.7%). There are many apartments in old buildings that do not have water meters. According to the data presented in the tables below, this represents a substantial number of water meters. We estimate that by installing internal water meters in old apartment buildings, this total figure of approximately 175,000 water meters could reach 595,000 by 2020.

Reading water meters is mainly done manually, i.e., readings are taken by readers from the VIO Branch, who visit the measuring sites daily and record the status in manual, mobile devices ("visual" readings). These data are transferred to the VIO information system via a unique interface shown in Figure 2-1. Considering the available readers, over 580,000 readings are managed during the year. This results in an average of 3.3 readings per measuring site per year, which is insufficient given the required minimum of 12 readings annually (once a month) and which should align with the monthly billing cycle for customers.

In addition to "visual" readings conducted in the field, part of the readings for buildings in the city are carried out automatically through a remote water meter reading system based on M-Bus technology. According to the available data that can be found in Tables 2-3, the total number of pulse water meters installed in M-Bus systems is 44,340. Only 6,594 water meters (14.8%) can be read remotely (GPRS). The leading causes of such a situation are poor system maintenance and the unreliability of parts crucial for measuring water consumption. Adjusting the impulse control - reed relay). According to the previous General and technical conditions for the delivery of water services [12], the maintenance of the M-Bus system is the responsibility of the building owners, who, unfortunately, do not maintain these systems well enough. For this reason, most of the M-Bus local networks are defective; that is, it is impossible to read them remotely.

Figure 3.3: A mobile device for collecting meter readings (DOLPHIN 7900)

In addition to the "eye" reading in the field, part of the building reading is automatically done in the city area through a remote water meter reading system based on M-Bus technology. According to the data the total number of pulse water meters installed in M-Bus systems is 44,340. Only 6,594 water meters (14.8%) can be read remotely (GPRS). The leading causes of such conditions are poor maintenance of the system and the unreliability of parts crucial for measuring water consumption (for example, the adjustment of the pulse irrigator - reed relay). According to the previous General and technical conditions for the delivery of water services [12], the maintenance of the M-Bus system is the responsibility of building owners, who, unfortunately, do not maintain it well enough. These systems. For this reason, most of the M-Bus local networks are defective; that is, it is impossible to read them remotely.

FIGURE 3.4: M-BUS, SECONDARY WATER METERS AT LOCATION VRBANI III, KUTNJAČKI PUT 10

Today, VIO has several payment systems supported by various IT applications. Some of the applications are supported and implemented within the Branch, such as the systems RISOV and RINUS, and some are implemented outside the branch, such as ISNPV (company APIS) and several smaller billing systems for calculating the consumption of apartments with internal water meters. The total number of invoices delivered from these systems for the areas of the City of Zagreb, Samobor, and Sveta Nedjelja is over 380,000. According to the indicators of the United Nations8 (Figure 3-1), more and more inhabitants will live in cities (by 2020, even over 80%). The increasing number of inhabitants will make life in the city more and more complex. Information systems, which can manage energy resources, will play a significant role in the sustainable development of such cities. Adaptation to new, "smarter" technologies will be considerable if one wants to achieve the necessary organization and efficiency, which will undoubtedly increase investments in advanced and intelligent networks (smart grid - smart city).

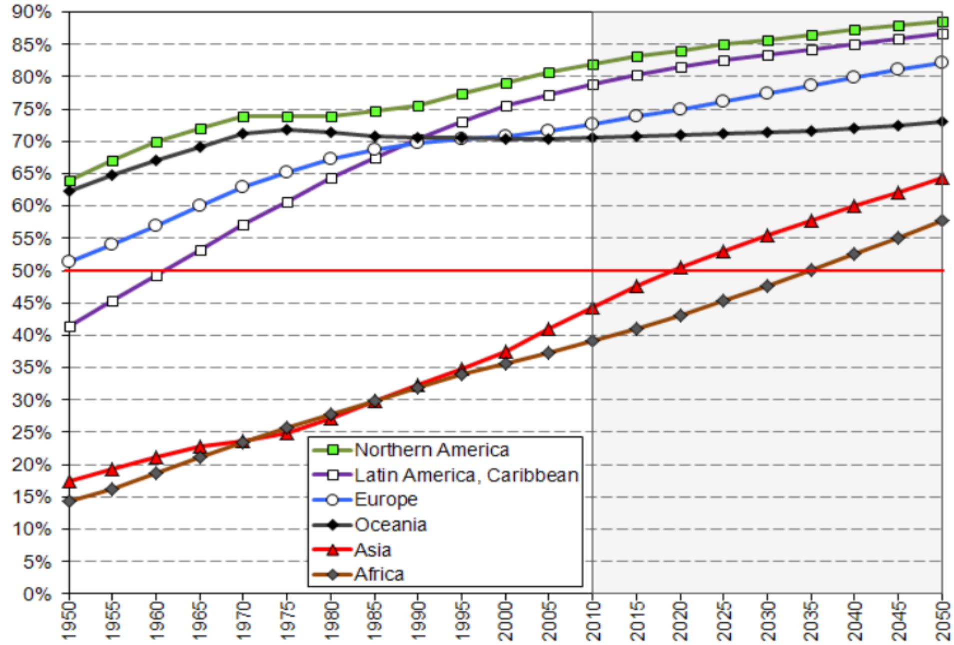


Figure 3.5: Population movement in the world until 2050 - the population living in cities.

The realization of intelligent networks today is possible with a wide range of ICT solutions, and choosing the right solution is not a simple problem and requires a lot of experience and professional knowledge. Before developing a brilliant (but expensive) city network, many questions are asked. One can find the following among them: "What do the wise do with smart networks?". The answer to that question is provided by the energy sector, which in this way received a robust infrastructure, which achieves long-term savings that will pay for itself and, at the same time, bring significant improvements to the energy supply and distribution system (through increased energy efficiency). At the end, the question arises: "Is there an alternative?". It seems to us not only if we are not ready to accept development that requires knowledge, experience, and significant investments.

3.3. Data Collection Procedures

The Automatic Meter Reading (AMR) system has been implemented in the City of Zagreb through the installation of the M-BUS system for the remote reading of gas and water meters in new buildings since 2000. The M-BUS system is based on bus architecture specifically designed to read consumption data for gas, electricity, and water and utilize two lines (buses). These buses are defined by EU standards (EN 13757-2 for the physical and link layer, EN 13757-3 for the application layer). A wireless version, Wireless M-Bus, is also defined by EU standard 13757-4. The M-BUS operates on a hierarchical system, with communication managed by a central unit (master). A two-wire communication cable can connect multiple auxiliary units (enslaved people) to the controller device. Various devices for remote data collection can be connected to the master unit according to the central billing system. These devices can include multiple communication technologies such as modems, GSM/GPRS devices, and ADSL connections. Collecting water consumption data from the central unit is also possible by having readers use handheld antenna devices (walk by) or remotely via vehicles (drive by).

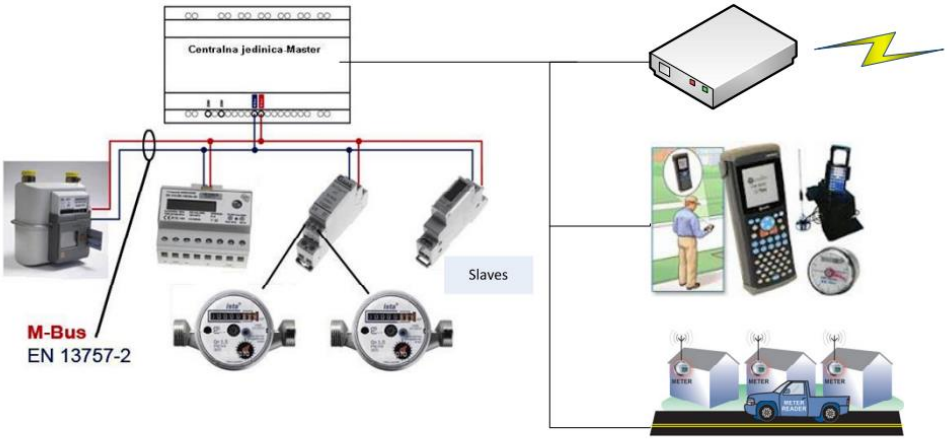


FIGURE 3.6: M-BUS, Principal scheme, and method of connecting AMR to the billing system

Based on the analysis presented in Table 2-3, it is evident that the current M-BUS system is not performing adequately. Of all the pulse water meters installed in the City of Zagreb, only 14% meet the criteria for accurate readings. Consequently, manual readings are conducted at these locations. The primary factors contributing to this issue are the subpar quality of the pulse water meters (specifically the reed contacts) and insufficient maintenance of the overall M-BUS system, which, as per previous regulations, was the responsibility of the investor/user.

Despite the limitations discussed in previous chapters, M-BUS systems still hold potential. While they struggle with remote bidirectional connections and automatic integration with billing systems, they can effectively perform their core function of local reading at the building level or local area network (LAN). The key lies in linking them to a remote system through an advanced AWMR network, essential for creating an intelligent water meter framework.

The primary goal of this network is to establish a direct, bidirectional connection between intelligent water meters and the billing system (billing UPN). This connection provides essential information and services related to consumption and billing through an online customer portal (MY WATER). To achieve this, local water meter networks at the building or city district level must be connected to the remote system. This process requires constructing access points, typically at water supply facilities within zones II and III of the water supply system or on high-rise buildings throughout the city.

According to the AWMR network concept, access points (AP) will connect to the server to collect water meter readings (MARS - Measurement and Automated Reading System) via ADSL infrastructure. MARS collects all readings and ensures this data is delivered to the billing system (UPN). In addition to linking local networks (LAN) to remote networks (WAN), the AWMR will facilitate the development of home area networks (HAN) in the future, allowing customers to monitor their local energy systems using smart tablets or displays.

3.4. Research Design

Smart City and Smart Grid are becoming increasingly present and inseparable synonyms for an organized city system in recent times, in which residents' lives are made much easier thanks to the organization established with ICT technologies, which provide detailed information from all segments of the city organization daily. Life. The goal of every smart grid should be its primary functionality to manage energy resources efficiently, i.e., to assume the primary role in systematic energy management (SGE). The SGE principle makes it possible to achieve the optimal level of energy efficiency (EE) of the system in such a way that the same or even better effects can be obtained with less consumed energy while at the same time maintaining or even increasing productivity or the standard of living. Less energy consumption, on the one hand, allows us to reduce the emission of greenhouse gases. On the other hand, we protect the ozone layer, which is ultimately the true meaning of intelligent networks. To clarify the functioning of the innovative network, it is perhaps best to compare it with the model of the human "Smart Organism"10. The most essential parts of such an organism are the senses (sensors), the brain, and the nervous system, which are responsible for establishing a control connection with the body of a living organism. The senses generate and shape information and the nervous system sends it to the brain, responsible for its storage, processing, and decision-making. After processing, the brain sends information to the extremities. Through teamwork of all parts of the organism, we are ready to manage daily tasks and constantly learn based on such experience. Behind every experience comes new knowledge and the possibility for new conclusions, which is a constant cycle of development and upgrading of the intelligence of our organism. Without such an intelligent system, our species would have disappeared from the face of the earth "a long time ago." The comparison of a Smart City with a "Smart Organism" shows how "alive" such an innovative city system must be and how vital a sufficiently fast and reliable data-information exchange is in such a system. Let us imagine what could happen if our hands are above the fire, and our nervous system is slow or gives wrong information (e.g., instead of feeling hot, it provides the information that it is pleasantly warm). Similarly, we can imagine what happens in a system in which, for example, data on the status of an energy source comes to the billing system irregularly or incorrectly. Such a system is almost certainly very unreliable for users, inefficient, or of little benefit from such a system. In such a system, we cannot talk about establishing high living standards or managing energy efficiency. Realizing a Smart Network in a Smart City requires good preparation and development programs, and we hope that this Study, which tries to look at the realization and development of a specific AWMR network from as many development perspectives as possible, will be helpful in our case. Setting goals and guidelines according to which it should be leading to the development of the network will have a crucial role in its implementation. What we consider unusually important in our case are two fundamental development-strategic goals: user requirements and increasing energy efficiency.

The core of the smart grid is automatic meter reading (AMR). AMR refers to a remote reading system that consumes energy resources such as electricity, gas, water, and heat. It facilitates data collection and storage and connects customer accounts at measurement points. Advances in information and communication technologies (ICT) have significantly enhanced AMR, allowing for the immediate, automatic transfer of remotely read and stored data to central billing systems. This setup is part of an advanced metering infrastructure (AMI) framework.

Advanced measurement systems are typically structured into communication networks where numerous nodes gather data from measurement devices and transmit it to a central node. As these networks are primarily wireless, careful consideration must be given to selecting the appropriate protocol, frequency channel, and modulation for communication. From a technical standpoint, this choice is determined by addressing several key questions. Factors influencing this decision include:

I. the distance the signals must travel
II. the environmental configuration (obstacles, reflections, etc.).
III. antenna specifications (dimensions, sensitivity)
IV. calculated power interference output and channel selectivity
V. volume of data produced by the system and network throughput.

In the context of advanced metering, the 868 MHz and 169 MHz frequency bands are predominantly utilized, as the decline in the use of the ERMES system and transmitters has liberated communication channels, some of which are now designated for advanced metering systems (draft EN13757-4). For devices operating at these frequencies, the following criteria must be met:

I. Suitable RF transceivers with high selectivity, sensitivity, and strong blocking characteristics
II. system MCU core with minimal power consumption
III. Topology that facilitates the design of an efficient power supply system (if devices are not battery-powered)
IV. battery-operated devices should possess extended autonomy (five years or more).

Standardized solutions like WMBus, ZigBee, 6LoWPAN, and 802.15.4.G are already in use in the advanced metering sector, with WMBus being the only one governed by a European standard for wireless metering, applicable to all types of meters, including electrical ones. The performance quality of devices is determined by high receiver sensitivity, the ability to filter interference from other devices within the same frequency band (selectivity), and the capabilities of filtering devices operating in adjacent and distant bands (blocking). Given the multitude of protocols and devices sharing the same frequency band (such as meters, alarms, wireless audio transmission, LTE base stations, etc.), interference becomes a significant issue, severely constraining system design. Alongside the performance quality of radio frequency devices, energy consumption is a primary consideration when designing such systems. In modern sensor networks, communication stands as the largest energy consumer. Sensor nodes must keep their communication components inactive for most operational cycles to extend their lifespan. Consequently, various synchronization mechanisms for transmitters and receivers have been developed. The ZigBee standard operates on the premises of devices having a constant power source, which leads to a lack of energy-saving mechanisms for routing nodes, limiting the battery life of devices in ZigBee networks to only a few days and thus significantly constraining their application potential [35]. As a result, employing the IEEE 802.15.4 network is advisable, as it enables the implementation of sleeping repeaters, allowing for... Duration and acceptable device lifespan (minimum battery life of 5 years) – or network.

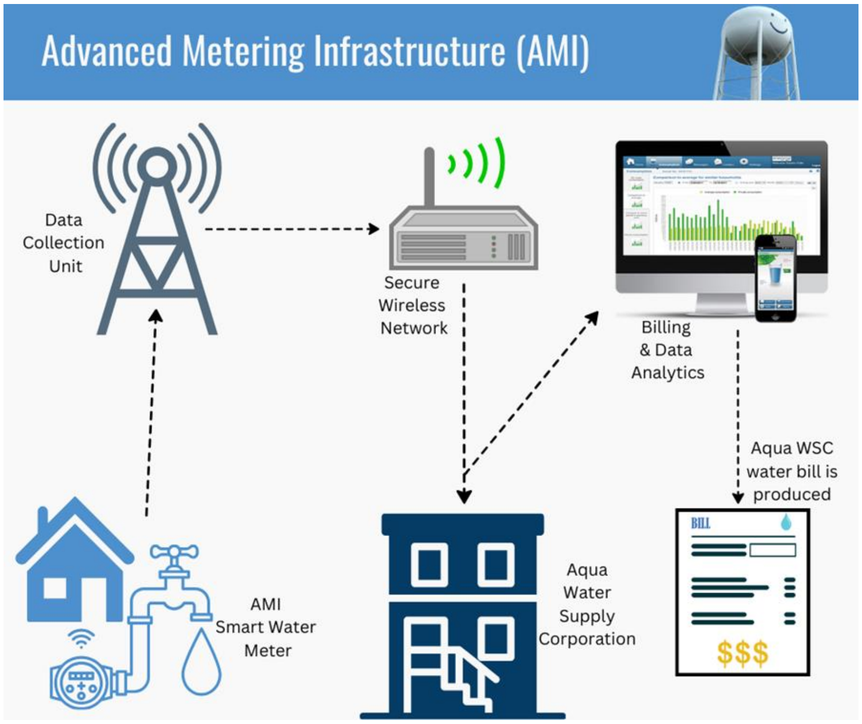


FIGURE 3.7: Concept of neoprene network

3.5. Conclusion

ICT technologies have recently established a strong presence in the energy market. The traditionally stable energy sector is currently facing challenges to its long-term stability unless there is an increase in short-term investments to enhance business operations and achieve cost savings. The urgency is amplified by climate change and dwindling energy resources. Concurrently, opportunities for ICT's involvement in this sector are expanding daily, particularly with several European Union initiatives focused on advanced metering. The advancement of smart grids and the integration of intelligent ICT solutions are priorities in the Digital Agenda, which emphasizes collaboration between the ICT industry and governmental bodies to develop technologies for smart grids and smart meters. This cooperation is crucial for the evolution of energy-efficient buildings (near-zero energy buildings) and intelligent transportation systems, which align with the 20-20-20 targets. In December 2008, the European Council approved a climate and energy change package, mandating EU member states to achieve the following by 2020:

I. Decrease greenhouse gas emissions by 20%
II. Incorporate 20% renewable energy sources
III. Reduce primary energy consumption in the EU by 20%

These stipulations compel member states to undertake significant reforms and launch initiatives to meet these ambitious objectives quickly. The European Commission anticipates that the ICT sector can help mitigate greenhouse gas emissions through three primary approaches:

Facilitating energy savings in the global economy, particularly in high-consumption sectors such as construction, transport, and manufacturing

Transitioning towards a less materialistic economy where remote work, e-commerce, and cloud computing contribute to substantial energy savings

Implementing energy consumption measurements in households, energy networks, and industries while promoting awareness of the importance of energy conservation

It is not surprising that the European Commission holds high expectations for ICT, given its transformative impact on business practices and daily life across various sectors. This environment presents a long-awaited opportunity for advanced metering projects, which have the potential to provide accurate energy consumption data to a wide range of stakeholders, from individual users to governmental entities and the European Commission itself. However, advanced metering technologies still lack the maturity to make high-quality, precise decisions at the upper levels of governance.

At the technical level, the development of advanced metering has been hindered by several factors that restrict the potential progress of these solutions in Croatia. These constraints include:

I. A lack of universal solutions that offer minimal installation and maintenance costs (due to the existence of numerous incompatible measuring devices and advanced metering systems)
II. A diverse array of technologies, communication channels, and protocols are employed in current solutions.
III. Solutions are needed when multiple utility companies and government entities require access to the same data.

While numerous EU projects have successfully accelerated standardization processes and helped define appropriate technologies in advanced metering, much work remains. Many standards, such as DLMS/COSEM [40], offer a common foundation for future interoperability; however, the current landscape features a variety of proprietary solutions that impede genuine competition among manufacturers and highlight challenges in achieving a universal solution across all systems. Consequently, VIO has prioritized developing its solution, which will, through its flexibility and modularity, allow for the reading of various water meters, irrespective of their manufacturer.

Chapter IV:
RESULTS

4.1. Design Control Activities

Management should design control activities to achieve objectives and respond to risks. The following attributes contribute to the design, implementation, and operating effectiveness of this principle:

I. Response to Objectives and Risks
II. Design of Appropriate Types of Control Activities
III. Design of Control Activities at Various Levels
IV. Segregation of Duties

Management designs control activities in response to the entity's objectives and risks to achieve an effective internal control system. Control activities are the policies, procedures, techniques, and mechanisms that enforce management's directives to achieve the entity's objectives and address related risks. As part of the environmental component control, management defines responsibilities, assigns them to critical roles, and delegates authority to achieve the entity's objectives. As part of the risk assessment component, management identifies the risks related to the entity and its objectives, including its service organizations, the entity's risk tolerance, and risk responses. Management designs control activities to fulfill defined responsibilities and address identified risk responses. Management designs appropriate control activities for the entity's internal control system. Control activities help management fulfill responsibilities and address identified risk responses in the internal control system. The standard control activity categories listed are meant only to illustrate the range and variety of control activities that may be useful to management. The list is not all-inclusive and may not include control activities that an entity may need.

4.2. Digitizing Public Sector Water Supply Operations

As industrial strategies increasingly embrace the industry 4.0 paradigm, characterized by high-tech advancements, manufacturers are relentlessly enhancing their products to align with the digital business landscape. Modern products are sophisticated and designed for seamless integration within interactive cyber-physical systems.

This evolution presents a dual-faced scenario to various organizations, including those in the water supply sector: a realm of new opportunities and challenges. The publication examines the shift in water supply entities toward addressing the digital transformation challenges within the industry 4.0 framework. A notable initial challenge is the transformation of water supply infrastructures into cohesive cyber-physical systems (CPS). Moreover, organizations must adapt to an abundant ecosystem in Big Data and develop a capacity for deploying innovative, predictive IT solutions. It asserts that water supply groups must evolve beyond traditional practices to sustain business viability while capitalizing on technological advancements and available opportunities.

Digital transformations have revolutionized virtually every sector, integrating digital technology into diverse facets of society, including academia, healthcare, media, politics, and commerce. This shift has redefined conventional business practices and enhanced client and customer engagement strategies. According to the German Water Association (GWP) 21 study, Figure 4.10 illustrates digitalization aspects and their relevance to organizations.

Water supply entities are transitioning into proactive, real-time responsive organizations capable of detecting positive and negative shifts and swiftly strategizing for operational improvements. The significance of digitization is emphasized through two primary initiatives:

While periodic reports hold initial value, their relevance wanes over time. A more effective approach is real-time business reporting, utilizing Business Intelligence (BI) to constantly monitor key performance indicators (KPIs) for timely and necessary adjustments.

Customer Relationship Management (CRM) systems facilitate the management of interactions between businesses and current or prospective clients. This foundational element of digitalization streamlines communication processes in contracting, sales, and billing. The logical extension includes integrating Automatic Meter Reading (AMR) systems for remote water meter tracking.

The GWP has significantly aided the water sector's digital transition by creating the WATER 4.0 working group, issuing a publication outlining the WATER 4.0 idea, and highlighting the value of digitization across various user groups. Their findings recognize the nonsingular nature of digital solutions; users' needs dictate the specific type of digital integration for water supply processes. GWP case studies demonstrate diverse digitization applications throughout the value chain and integrated systems. Experts on digitization processes concur that a strategic, well-considered approach is vital, considering the importance and perspective of the processes to be digitized.

GWP findings show that water suppliers establishing intelligent networks generally tune in with digital trends.

The WATER 4.0 working group situates digitization and automation at the heart of their strategy for resource-efficient management and competitive water administration. In this context, CPS is pivotal in optimally interlinking the cybernetic and physical facets of water infrastructures, fostering intelligent connections between agricultural, industrial, and domestic water resource consumers with SMART system components embedded within a sustainable water framework. Moreover, the WATER 4.0 initiative promotes transparency in the water usage of present-day consumers, addressing the demands for a sustainable, innovative approach to environmental management. According to GWP, Water 4.0 is not a specific technology but a collaborative concept that leverages connected, advanced technologies with water as a central focus. Water 4.0 is a nexus for natural resources, consumable products, or industrial assets. The principal aim is to promote sustainable management and utilization while mitigating risks, considering the stakeholders' varied interests. By integrating sensor networks, controlled systems, analytics, and modeling, data is transformed into actionable insights that can guide decision-making, enact strategies, and provide feedback on interventions in water systems. Over time, accumulated information can yield more profound insights into optimizing water usage across various uses. Water 4.0 embodies a progressive, integrated approach, keeping pace with technological advancements and enabling informed, sustainable decision-making processes.

The GWP's brochure highlights case studies, including the initial CPS water systems applied in drainage and flood prevention and SMART water consumption tracking in Darmstadt.

Sirkia (2017) explores the role of data resources and information systems in water supply and sewage services, focusing on small to midsize utilities. They emphasize the importance of vast datasets, open data, and the systems managing them. Their investigations suggest that water supply entities stand to gain by enhancing their data assets, requiring improved competency in data management, technology, and security.

Teixeira de Azevedo (2019) and his team discuss the digital revolution's synergy with emerging technologies like the Internet of Things (IoT), big data, CPS systems, and cloud computing. They propose adopting these digital transformations into public water systems for efficient, wise water management.

In the study, Chopra and Gogia (2017) proposed a model for selling and managing drinking water via "water fountains," deploying digital tech in a non-traditional public water setup.

Cepa (2016) and his colleagues evaluate the impact of digitalization on utility companies, particularly concerning water supply and sewage infrastructure. They examine how digitization can transform business models and stakeholder relationships, highlighting cost reductions from optimized asset management and advanced network control as critical motivators for adopting new digital solutions. They also suggest potential new revenue streams through additional services offered by utilities, asserting the strong influence of knowledge and technology on the sector's progression post-decades of operation.

Mutchek and Williams (2014) paper addresses urban water systems' sustainability and resilience hurdles, including water loss, resource overuse, water quality, and disaster response. They advocate for information and communication technology (ICT) in developing intelligent water networks that automate and coordinate monitoring and control. Despite advancements in specific system elements like smart meters, they note the scant acknowledgment of intelligent networks. The authors call for heightened awareness and integration of these technological components into intelligent systems, underscoring the advantages of sustainability and resilience. They acknowledge the challenges in implementing these networks, citing financial constraints, economic deterrents, and entrenched institutional and political conventions. They maintain that successful examples underscore their benefits and facilitate further intelligent network adoption. Dan Koo and colleagues discuss in their study that meter reading plays a vital role in securing the flow of revenue for water supply entities. The manual approach to meter reading is known to be both time-consuming and expensive, leading to various, largely unsuccessful, efforts to automate this process.

Automatic Meter Reading (AMR), a system for automatically collecting consumption, diagnostic, and status data for water and energy meters, has significantly advanced technological adoption within the water industry. AMR facilitates automatically transferring this data to a centralized database for billing, troubleshooting, and analytical purposes. By 2013, AMR had been implemented in over 40 percent of U.S. households, demonstrating substantial progress. This system has notably eradicated the need for personnel to read costly and less dependable manuals. Water providers can process billing more efficiently and precisely as they move away from estimates and toward actual consumption data, thereby reducing operating expenses. Additional advantages include heightened accuracy and a more uniform meter inventory, contributing to a clearer understanding of water loss and supporting improved pipeline maintenance or replacement diagnostics. Initially, AMR systems depended on wired connections, which became impractical given the extensive distribution of meters. Over time, AMR has evolved with IT network technologies, leading to intermediate systems that permit meter readings through on-site visits such as walk-by or drive-by methods. This intermediate approach paved the way for the latest AMR technological leap, which employs sophisticated wireless communication via electronic networks, as depicted.

The authors elaborate on Big Data as an emerging technical paradigm that entails gathering vast quantities of pertinent data from sensors tasked with monitoring structural and usage parameters and system efficiency. Such extensive data collections are made possible by deploying Internet of Things (IoT) technology across the water service infrastructure and customer usage points. Their work outlines the progression of an IoT system designed for the extensive collection of water consumption data, structured into two streams: downstream data informing consumers about their water use and system performance and upstream data providing insights akin to those generated by traditional SCADA systems for the benefit of water supply companies. Additionally, the authors consider the conceptual trajectory of IoT and Big Data within water supply systems, highlighting the advantages and acknowledging the constraints. They underscore the necessity for a shift from reactive to proactive maintenance within public water supply networks and argue for the seamless and effective integration of IoT and Big Data technologies as a strategic direction toward fostering such a proactive system. Although this technology is not yet available for water supply infrastructure, they predict it will become crucial in constructing innovative and sustainable urban environments.

The document presented the Singapore Municipal Council's blueprint for an advanced public water supply concept. The council envisions implementing a Smart Water Grid, an intelligent network that aligns with its mission to provide superior water quality to its consumers. The grid employs sensors and analytical tools distributed across the service area, enabling the council to manage water provision with enhanced efficiency and sustainability. The Smart Water Grid guarantees Singapore's population a reliable and future-proof water supply.

The Singapore Communal Council (2016), in their study, has outlined five fundamental elements for their innovative Smart Water Grid (SWG) relating to water supply: management of the system, monitoring of water loss, scrutinizing water quality, automatic meter readings at consumer endpoints, and water usage efficiency. Each element is examined in terms of the challenges presented, the current technology in place, the practical experiences of the Singapore Municipal Council, and the identified technological gaps that need to be addressed to achieve better management and oversight. Enhancements to water supply systems and the implementation of rigorous preventive measures for pipelines at high risk can significantly curb the frequency of breaks and events stemming from poor water quality. Upgrades to the infrastructure with sensors for instantaneous pressure tracking and water quality will transform existing water supply networks (WSNs) into intelligent systems. These systems are equipped with the necessary documentation and instruments for the swift handling of any incidents. Consumers will benefit from immediate updates on their water usage from automated meter readings, empowering them to make informed choices regarding water conservation at home or in their enterprises. The SMART water connection concept utilized is illustrated in Figure 4.1.

Figure 4.1: SMART water supply connection concept

In the study by Priya and Rameshkumar (2017), the emergence of smart cities and the escalating demand to fulfill the goals and capabilities of their inhabitants are analyzed. They advocate for deploying a water supply management system that leverages sensor technology and computing power to meet water requirements for demand, purity, and oversight. They recommend the management of water infrastructures through sensor data processed by computers, with communication facilitated through computers or wireless mesh networks.

Lin, Sedigh, and Miller (2011) conducted a comprehensive CPS (cyber-physical system) simulation for an advanced water supply network. They begin with initial simulations of water networks, varying from basic to multifaceted systems, aiming to evaluate the influence of digital administration and governance on actual infrastructure networks. These simulations are intended to closely mimic the workings and interactions between the cybernetic and the actual physical components within the system to discern the interrelations between cyber and physical infrastructures. Water Distribution Networks (WDNs) represent a new cyber-physical arena where physical elements like pipes, valves, and storage vessels are interconnected and regulated by computer systems, ensuring efficient distribution.

The primary function of WDNs is to provide the populace with safe drinking water consistently. Data on demand patterns, water quantity (such as flow rates and network pressures), and water quality (concerning pollutants and mineral content) are vital for targeting maintenance actions and pinpointing areas needing advanced detection and monitoring. Sensors dotted across the physical framework gather information, which is fed into digital algorithms. These algorithms aid in making decisions that guide the physical mechanisms responsible for managing the distribution and purity of the water. Due to the inability to directly observe essential infrastructure, it is necessary to employ modeling and simulation to explore the viability of CPS systems. As water supply systems expand and become more intricate, the question of their dependability and efficacy arises. The authors acknowledge the benefits of simulating these systems but highlight issues arising as simulations scale up.

In their paper, Stoffels and Ziemer (2017) explore the current digital landscape in the water industry. They evaluate the feasibility of applying a tiered modular product structure to process industries and consider the role of a digital commercial strategy. Their findings indicate that digital technology adoption is perceived as a crucial avenue for future business expansion, though significant obstacles mar its practical application. Their research also reinforces the view that organizations with a digital strategy are better poised to innovate new business models during digital transformations. While the process industry has historically embraced process optimization technologies, digitization represents a profound change that surpasses traditional technological progression.

The dynamics of innovation within the water sector, looking at both water supply and management entities to establish the groundwork for future studies. They highlight an immediate necessity for innovative approaches in the water sector to address many complex challenges, noting that this sector is generally less creative than others. Their research lays the groundwork for future investigations into integrating contemporary knowledge within the water sector. They conclude that embracing change requires a comprehensive examination and development of indicators, tools, and methods, as well as innovations that provoke structural changes, thereby impacting competitiveness, employment, efficiency, and broader economic outcomes, all essential for equitable and sustainable water usage in the short and long term. In the publication, the researcher highlights that managing water loss in municipal water systems is a crucial responsibility of public utility providers. Water losses form the foundation for assessing these systems' quality and operational efficiency. The researcher further explains that water losses are typically evaluated by studying water flow and usage patterns over extended periods, taking a long-term perspective for the analysis. While the resulting data from this analysis serve as recommendations, they fall short of providing reliable, actionable insights for proactive system management. Instead, collecting and interpreting data in a real-time context offers a more accurate reflection of the system's performance in terms of quality and efficiency.

Moreover, an alternative approach involves the early detection of changes within the water system. This consists of integrating intelligent meters into a novel IoT-based water supply framework. This strategy, which capitalizes on the continuous monitoring of water flow and consumption and the capability for real-time data access, ushers in a transformative approach to managing water losses in public water supply systems.

In their investigation, Kober and Gangl discuss the significance of minimizing water losses not only from technical standpoints but also from economic and environmental perspectives. They note that pinpointing leaks is straightforward with current technologies like acoustic sensing and correlation techniques. The key challenge lies in establishing an effective monitoring network that promptly detects and localizes emerging or existing leaks. They criticize the strategy recommended by the IWA of segmenting water systems into District Metered Areas (DMAs) as incomplete, highlighting issues such as stagnation or diminished hydraulic performance. They recommend establishing a loss monitoring system by strategically placing sensors within the water network, leveraging telecommunication networks, and employing GPRS or GSM technology to address this. These strategically placed sensors facilitate the detection of minimal nocturnal flow rates that deviate from standard levels, allowing for the accurate identification of leakages.

The comprehensive evaluation of sensor data alongside established standards significantly simplifies pinpointing the exact location of water losses.

The publication explores SMART approaches for public infrastructure, including water supply systems. The paper proposes enhancing current systems by integrating contemporary insights and technologies from Industry 4.0. This vision is encapsulated, which presents a sophisticated CPS-based water network framework.

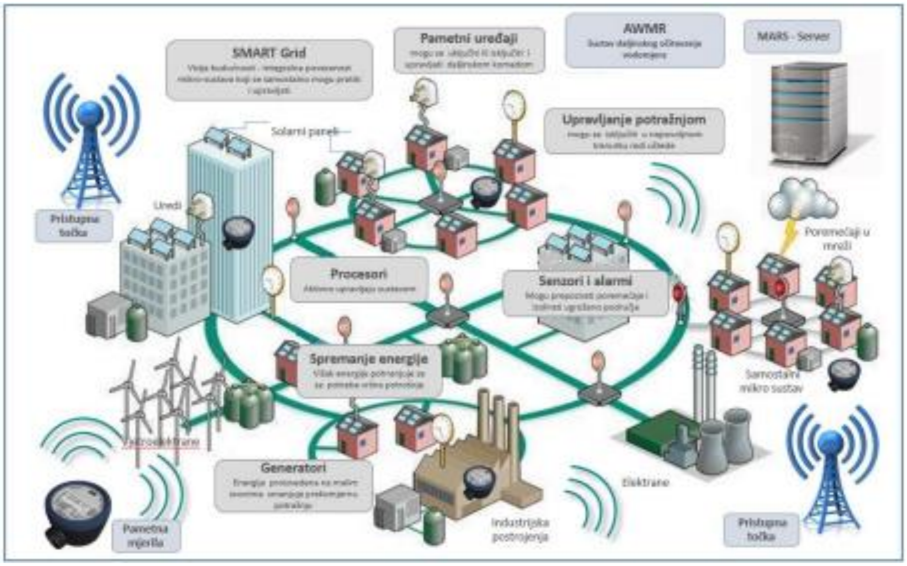


Figure 4.2: Innovative CPS water supply network concept

Integrating "SMART" technologies in the energy and utilities sector presents a prime opportunity for rapid advances, yielding improvements in service quality, efficiency in management practices, customer satisfaction, and reduced operational costs.

4.3. DMA Zone

Water loss is a common challenge in all water supply systems, and effectively managing these losses is crucial for public suppliers and distributors. Depending on the system's specific characteristics, a strategy is adopted, and the optimal method is selected. The use of a zoning method, introduced by the Water Loss Task Force (WLTF) group in the middle of the 20th century, has gained practical significance and importance during the rapid development of water supply systems.

The fundamental concept of this method involves dividing the water distribution system into smaller, more manageable subsystems known as controlled zones for easier monitoring and management. These controlled zones, DMA zones, are established with precise measurements of water entering and leaving the zone. The disparity between the water entering the DMA zone and the water delivered to end users as revenue water (RW) is termed non-revenue water (NRW), with most NRW attributed to actual water losses.

The number of DMA zones varies depending on the scale of the water supply system, ranging from single zones in small systems to over a hundred larger ones. Assessing water losses, quality, and efficiency within DMA zones enables the identification of problematic areas and facilitates planning for necessary monitoring, management, and maintenance activities. This proactive approach aims to detect faults in their early stage of development, minimizing the risk of pipeline ruptures.

Specific rules and influencing factors must be considered when forming and managing DMA zones and the overall water supply system to ensure their sustainability. Implementing DMA zones is a long-term commitment requiring thorough and proper execution to combat water losses effectively. Additionally, managing DMA zones, supported by specialized equipment and precise fault location techniques, is vital in reducing uncontrolled water outflows from the distribution water supply network.

However, conventional methods of assessing water consumption mainly relying on manual readings, pose limitations, resulting in delayed detection of defects and substantial direct and indirect damage. The irregularity and infrequency of water meter readings further complicate the analysis of flow and consumption within DMA zones, hampering early detection of water leakage.

To create a DMA zone, specific criteria must be fulfilled, especially the requirement to accurately measure the volume of water entering and existing in the DMA zone. The discrepancy between the water entering the DMA zone and the volume supplied to end users as revenue water (RW) is known as non-revenue water (NRW). The predominant portion of non-revenue water pertains to actual water losses.

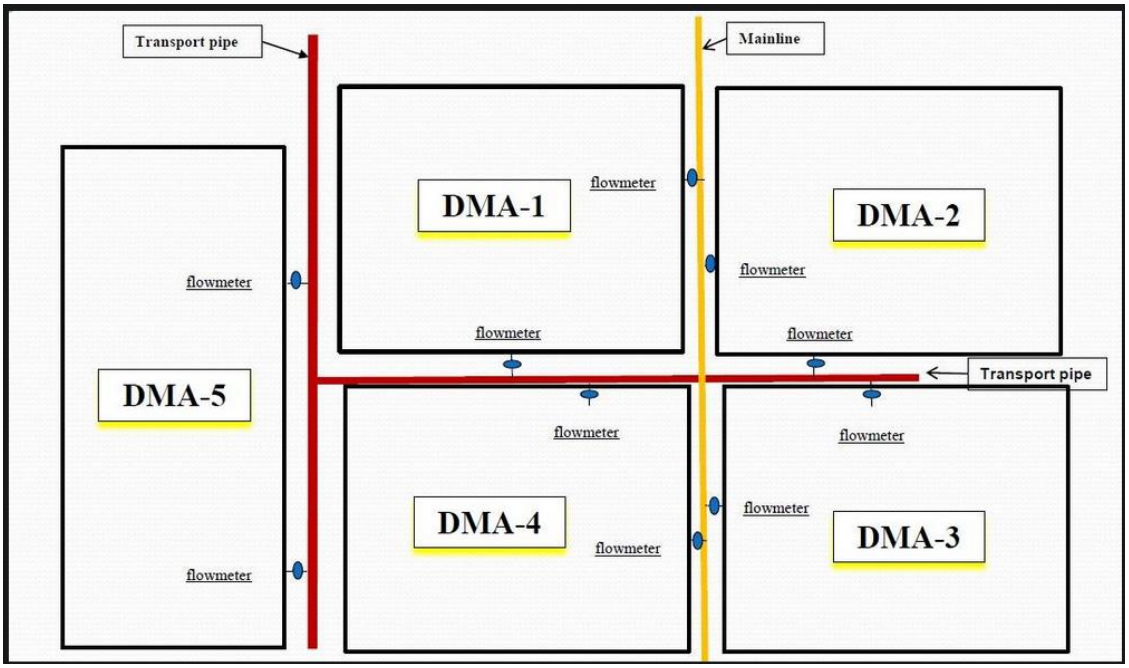


Figure 4.3: Schematic representation of the DMA zone

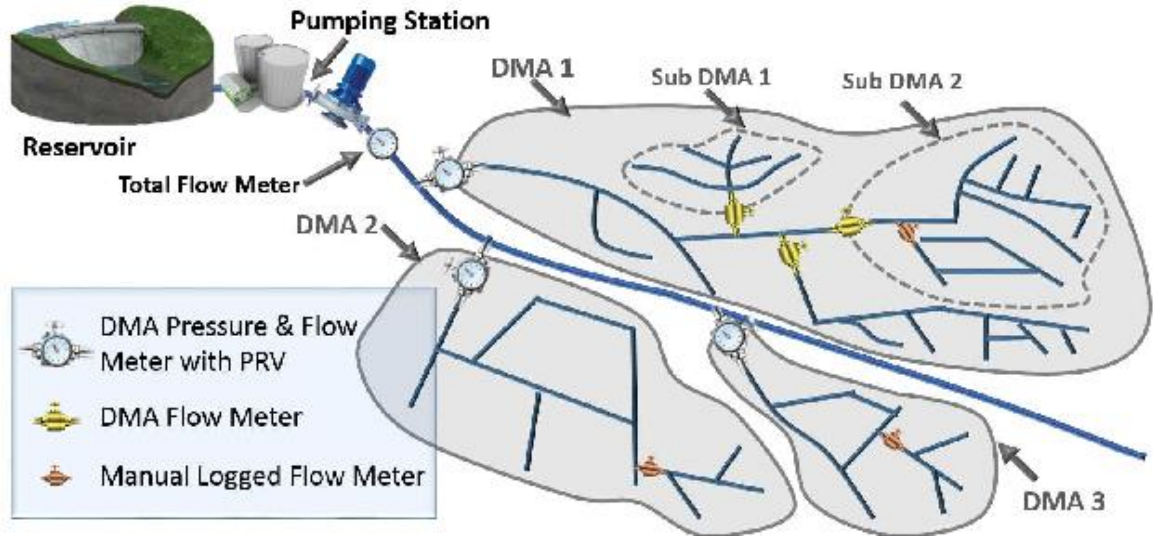


Figure 4.4: DMA-based water network architecture.

Most miniature water supply systems have a single DMA zone, while extensive systems may contain dozens or over a hundred DMA zones. We assess water losses, quality, and the overall efficiency of the water supply system by analyzing various DMA zones and comparing their quality. The measurements and analyses performed within these zones aim to pinpoint problematic areas, which helps plan and execute necessary monitoring, management, maintenance, or remediation activities for the water supply infrastructure. This process also enables the establishment of priorities and the dynamics of planned tasks. Within a DMA zone, the aim is to identify faults in their early development stage, especially before a pipe bursts, to facilitate predictive interventions. Once a potentially significant fault area is identified within the DMA zone (typically within a radius of several hundred meters), actions are initiated to accurately locate the fault for remediation. Specialized personnel utilize advanced equipment to identify the fault site precisely within the detected area. Managing DMA zones has proven to be an effective strategy for monitoring and minimizing uncontrolled water losses from the distribution network. However, relying on traditional metrics, primarily reported through personnel observation, dramatically limits our capabilities. Consequently, faults may go undetected for extended periods, resulting in substantial direct and indirect damage. Each DMA zone serves several thousand end consumers whose water meters cannot be continuously read, leading to issues with reading simultaneity. Generally, water consumption is recorded once a month or every few months, with interim consumption estimates used to generate monthly bills. These limitations complicate the analysis of flow and consumption within DMA zones and hinder the timely detection of water leaks.

4.4. Detection and location of water losses

Actual losses, as defined by the International Water Association (IWA), refer to the annual volume of water lost within a supply system due to various leaks, ruptures, and overflows in transport and distribution pipelines, water reservoirs, and service lines leading to the consumer's metering point. There are three primary methods to estimate actual losses:

I. Top-Down Annual Water Balance
II. Component Analysis of Real Losses
III. Bottom-Up Analysis of Night Flows or a combination of these methods

To calculate actual water losses (QRL) according to the IWA water balance, the formula used is

QRL = Q - QAC - QAL.

In this equation, Q represents the measured volume of captured water, QAC is the measured and estimated amount of authorized water consumption, and QAL refers to apparent losses. However, this method does not provide a detailed breakdown of individual loss categories, resulting in a lack of precision in pinpointing the contribution of each category to the overall losses. Consequently, it is generally utilized alongside one or both methods.

Based on the original "burst and background estimates" (BABE) method, the component analysis method effectively addresses water losses in supply systems. It categorizes leaks into reported bursts (RB), unreported bursts (URB), and background leakage (BL), each bearing distinct characteristics and detection challenges. The BABE method is characterized by its ability to differentiate between real and apparent losses, consider the effect of water pressure on the magnitude of losses, and assess loss levels during minimum night flows.

Additionally, the duration of water leakage is classified into observation time (Z), locating time (L), and rehabilitation time (S), each influencing the extent of water loss.

Figure 4.5: Invisible water leakage at the detected fault location [Internet]

Figure 4.6: Breakage of the water supply pipeline [source: Vodoopskrba i Odvodnja].

Figure 4.7: Fault undetected in time – indirect damage [izvor: Vodoopskrba i Odvodnja].

Unreported URB ruptures can be identified through various indicators, necessitating further activities using available technologies to locate the fault accurately. These include:

I. Closing the pipeline in sections for water leak detection (Step Testing)
II. Using a correlator for leak detection
III. Employing a geophone for leak detection
IV. Utilizing acoustic loggers for leak detection

In addition to the RB and URB classifications, the BABE method identifies a third category: background leakage. This refers to low-intensity water discharges (invisible leaks) occurring at multiple dispersed locations, complicating detection efforts. Critical aspects of the BABE method include categorizing total losses into real and apparent losses, analyzing the influence of water pressure on the level of losses, and assessing losses during minimal nightly flows. Daily water consumption patterns are established through measurements, and further analysis of these parameters can reveal the presence of invisible leaks due to pipeline faults, prompting actions to identify the fault's location precisely.

4.5. Digitization of business in the industry of public water supply

Encouraging industrial strategies should be based on Industry 4.0, wherein manufacturers continuously improve their products and quickly adapt to technological advancements in business digitization. Today's products are advanced and designed for seamless integration into interactive cybernetic-physical systems. Due to this digital transformation, many organizations, including water supply companies, are evolving significantly and facing new possibilities and challenges.

In a paper referenced as discusses the inevitable challenges caused by business digitization within the framework of Industry 4.0 in water supply organizations. These challenges include converting water supply systems into a single Cyber-Physical System (CPS), adjusting organizations to work within Big Data, and preparing organizations to apply intelligent and predictive IT tools. The conclusion is that water supply organizations must elevate their established methods to a higher evolutionary level while addressing the pressure for business sustainability and embracing new knowledge, technology, and opportunities.

Over the past several years, digital transformation has significantly impacted various aspects of life, integrating digital technology across diverse sectors, including science, health, media, politics, and business. Additionally, digitization has shifted organizations from passive to active entities, enabling real-time monitoring and the ability to swiftly adapt to positive and negative changes, thereby improving business operations.

Two critical directions for digitization exist: introducing real-time business reporting systems and implementing Customer Relationship Management (CRM) to effectively manage interactions with existing and potential customers. Embracing these directions can lead to automation in customer communication processes such as contracting, sales, billing, and remote readings for water meters.

The "WATER 4.0" group, established by the German water association GWP, has significantly promoted digitization in the water sector. They emphasize the importance of understanding that there is no one-size-fits-all solution for the digitization process and that different forms can be implemented in water supply processes based on user needs.

The WATER 4.0 concept bears similarities to the industry 4.0 concept, where Cyber-Physical Systems (CPS) are the core drivers, enabling optimal networking of cybernetic and physical components within the water system. This approach facilitates intelligent networking of water resources, including agricultural, industrial, and household usage, with SMART components in sustainable water infrastructure, promoting transparency and effective management of water resources.

The concept of WATER 4.0 involves the dynamic and holistic use of innovative water technology to ensure sustainable management, risk reduction, and consideration for the interests of all direct and indirect stakeholders. It fosters a networked approach wherein data is transformed into information to support informed decision-making and interventions in water systems. The German Water Association GWP also presents successful examples of adopting CPS water systems and SMART water consumption measurements.

Various researchers have pointed to the potential for digital transformations, including the application of technologies such as the Internet of Things (IoT), Big Data, CPS systems, and cloud computing, to enhance the effective management of public water supply systems.

Advancements such as the Automatic Metering and Reading (AMR) system have significantly improved the automation of collecting and analyzing water consumption data, leading to more efficient billing processes and reducing total business expenses. This technology eliminates the need for manual reading. It provides a precise and standardized inventory of water meters, offering better insights into potential water losses and facilitating more effective pipeline plumbing works.

The evolving AMR technology has transitioned from wired connections to advanced wireless communication technologies, improving data gathering and transfer efficiency and accuracy. This ongoing technological development illustrates the potential for continued improvement in the effective management of water resources through digital transformation.

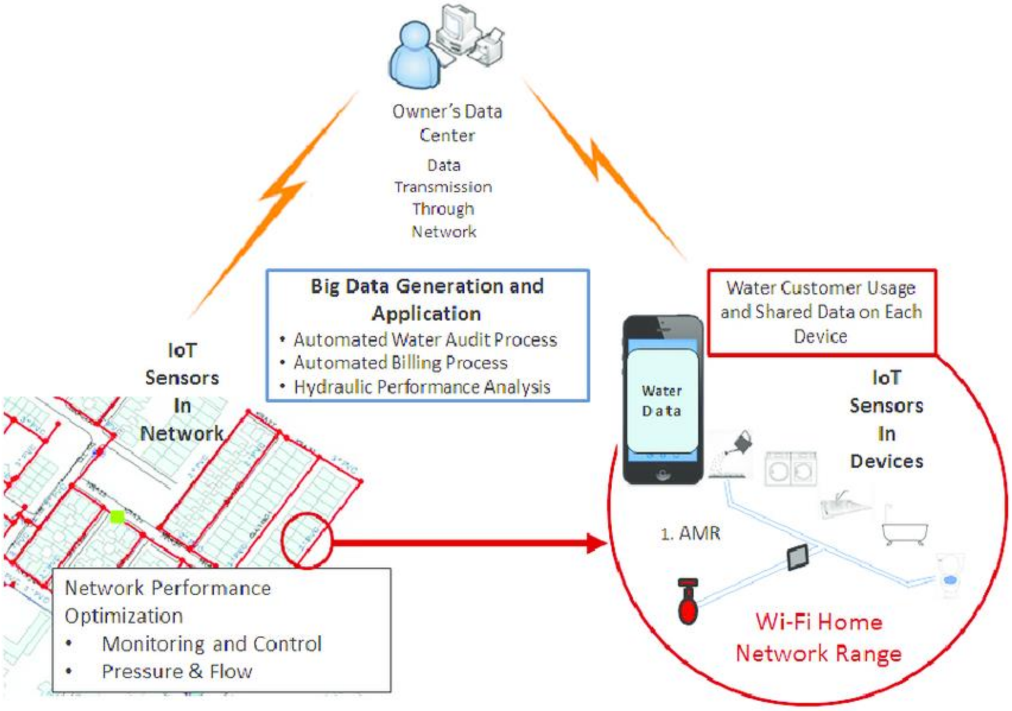


Figure 4.8: Application of IoT and BIG DATA in water supply

The authors propose that Big Data is a novel concept involving collecting large amounts of relevant data using sensors to monitor structural parameters, parameter usage, and system performance. This concept of collecting large datasets can be achieved by applying Internet of Things (IoT) technologies in water supply infrastructure, enabling water service providers to gather data from consumer activities. The authors present a schematic development of an IoT application for collecting large quantities of data related to user water consumption. This system involves wireless sensor networks (WSN) linked through an IoT platform to collect downstream and upstream data. Downstream data is utilized for water consumption and supply implementation, while water supply organizations use upstream data in a way that is like traditional SCADA systems. The paper discusses the conceptual development of IoT and Big Data in the context of water supply systems, emphasizing their advantages and limitations. The authors emphasize the need for proactive approaches in maintaining public water supply systems and suggest that integrating IoT and Big Data could offer an effective solution. They point out that while this technology is not currently available for water supply systems, it could be a key component of intelligent and sustainable urban infrastructure.

The Singapore Council has published its vision for intelligent public water supply systems to provide high-quality water to its customers. This vision involves the implementation of Smart Water Grid networks equipped with sensors and analytical tools to enable efficient and sustainable water supply management. The council's vision covers five critical aspects of the Smart Water Grid system, including managing water supply systems and reducing water losses, monitoring water quality, and implementing intelligent meters for automated water consumption readings. The authors describe a smart home concept for water supply in Singapore, emphasizing the importance of using sensors and computers to satisfy water demand, ensure water quality, and control water losses.

Additionally, the authors Priya and Rameshkumar discuss the upcoming era of smart cities and increased water consumption. They propose a model for managing water supply systems using sensory devices and computer works to satisfy water demand, control water quality, and manage water losses. Meanwhile, Lin, Sedigh, and Miller simulate intelligent water supply networks to evaluate the impact of digital management and control on the actual infrastructure.

Stoffels and Ziemer present a study on the digitization of the water sector, highlighting the importance of digital business strategies and the challenges faced in implementing digital technologies. They emphasize the potential for developing new business models during digital transformation and the significance of adopting digital technologies for future business development.

Wehn and Montalvo investigate innovation dynamics in the water sector, highlighting the need for innovation to address multiple challenges water supply and management organizations face. They emphasize the importance of integrating new knowledge and innovations into the water sector.

The authors further emphasize the importance of analyzing the sources of structural change and their influence on water sector competitiveness, employment, productivity, and economic performance to ensure water's fair and sustainable use.

In another paper, the author discusses the management of water losses in public water supply systems and the need to actively manage water systems with credible real-time data. IoT water supply systems are introduced to manage water losses effectively and efficiently.

Kober and Gangl stress the importance of reducing water losses from technical, economic, and ecological standpoints and propose using noise measurement and method correlations for leak detection and localization. They also suggest implementing a monitoring system for water losses by installing sensors in the water supply network and transmitting data through telecommunication networks.

Finally, the author of a different paper explores the application of Industry 4.0 concepts to advance existing water supply systems, emphasizing the potential for leveraging new knowledge and technologies to improve water supply networks.

Overall, this collection of papers emphasizes the integration of IoT, Big Data, and digital technologies as potential solutions for improving water supply systems and addressing the challenges faced by the water sector.

4.6. Guidelines for the development of advanced network infrastructure

According to United Nations indicators more and more inhabitants will live in cities (by 2020, even more than 80%). The increasing number of inhabitants will make life in the city more and more complex. Information systems, which can manage energy resources, will play a significant role in the sustainable development of such cities. Adaptation to new, "smarter" technologies will be considerable if one wants to achieve the necessary organization and efficiency, which will undoubtedly increase investments in advanced and intelligent networks (smart grid - smart city).

Today, a wide range of ICT solutions make the realization of intelligent networks possible, but choosing the right solution is not simple. It requires a lot of experience and professional knowledge. Before making a strategic decision to initiate the development of an innovative (but expensive) city network, many questions are asked, and one of them is: "What does the wise do with smart networks?"

The answer to that question is provided by the energy sector, which thus obtained a robust infrastructure. In the long term, this infrastructure will realize savings that will pay for itself and, at the same time, bring significant improvements to the energy supply and distribution system (through increased energy efficiency).

Ultimately, the question arises: "Is there an alternative?" It seems to us not, only if we are not ready to accept development that requires a lot of knowledge, experience, and significant investments.

4.7. Development of the "Smart grid"

Smart City and Smart Grid have recently become increasingly present and inseparable synonyms for an organized city system. This system makes the life of residents much easier thanks to the organization established with ICT technologies, which provide detailed information from all segments of the city's organization daily. Life. The goal of every smart grid should be its primary functionality to manage energy resources efficiently, i.e., to assume the leading role in systematic energy management (SGE).

The SGE principle makes it possible to achieve the optimal level of energy efficiency (EE) of the system in such a way that, in addition to

less energy used to have the same or even better effects while maintaining or even increasing productivity or standard of living. Less energy consumption, on the one hand, allows us to reduce the emission of greenhouse gases. On the other hand, we protect the ozone layer, which is ultimately the true meaning of intelligent networks. To clarify the functioning of the intelligent network, it is perhaps best to compare it with the model of the human "Smart Organism"10. The most essential parts of such an organism are the senses (sensors), the brain, and the nervous system, which are responsible for establishing a control connection with the body of a living organism. The senses generate and shape information and the nervous system sends it to the brain, responsible for its storage, processing, and decision-making.

After processing, the brain sends information to the extremities. Through teamwork among all parts of the organism, we are ready to manage daily tasks and constantly learn based on such experience. Behind every experience comes new knowledge and the possibility for new conclusions, a constant cycle of development and upgrading of our organism's intelligence. Without such an intelligent system, our species would have disappeared from the face of the earth "a long time ago."

The comparison of a Smart City with a "Smart Organism" shows how "alive" such an innovative city system must be and how vital a sufficiently fast and reliable data-information exchange is in such a system. Let us imagine what could happen if we have our hands over the fire, and our nervous system is slow or gives wrong information (for example, instead of feeling hot, it gives information that it is pleasantly warm). Similarly, we can imagine what happens in a system in which, for example, data on the status of an energy source comes to the billing system irregularly or incorrectly. Such a system is almost certainly very unreliable for users, inefficient, or of little benefit from such a system. In such a system, we cannot talk about establishing high living standards or managing energy efficiency. Realizing a Smart Network in a Smart City requires good preparation and development programs, and we hope that this Study, which tries to look at the realization and development of a specific AWMR network from as many development perspectives as possible, will be helpful in our case. Setting goals and guidelines according to which the development of the network should be guided will play a crucial role in its implementation. What we consider unusually important in our case are two fundamental development-strategic goals: user requirements and increasing energy

4.8. AWMR-VIO pilot projects

The issue of remote reading has been under consideration within the VIO branch since 2006, with various pilot projects attempting to address the challenges. However, these initiatives did not yield satisfactory results due to inadequate signal transmission from water meter shafts, difficulties in data transmission over long-range networks, and others. Consequently, previous pilot projects were suspended. A significant obstacle not adequately recognized during these pilots was the lack of integration between the remote reading systems and VIO's existing billing system. This meant that readings obtained through different methods were not directly transmitted to the VIO billing system but were read and transmitted indirectly by external service providers. This practice needed to change, leading to the launch of a new pilot in 2012—AWMR-VIO—based on a comprehensive, in-house developed solution. The pilot projects that were implemented and confirmed the technical and systematic solutions of this project are as follows:

- Knežija – Jarun Pilot Project
- Prilaz Slava Raškaj no. 9 (PSR9) Pilot Project
- Subsidiaries of Zagreb Holding, Cleanliness, and VIO Pilot Project
- Mamutica; Božidara Magovca 63 Pilot Project
- Vrbani III – SDM Pilot Project

4.8.1. Pilot project 1

The initial pilot for the AWMR project was carried out at nine locations in the southwestern area of Zagreb. An access point was established at the Končar INEM building, located at Fallerovo šetalište 22, 2.5 km from the furthest site, Jarunska 3. In February 2012, equipment installation began at these locations, including water meters with pulse output (ZGH VIO) and telecommunication devices such as data loggers and concentrators (Končar INEM equipment). Additionally, the MARS (Measurement and Remote Reading Software) application by Končar INEM was implemented for software support. This first pilot aimed to address several critical questions: Can this technology retrieve a signal from a water meter several meters underground, despite a heavy metal maintenance hole cover, and wirelessly transmit it to the concentrator and then to the remote access point? How robust is technology under the humid conditions of a maintenance hole? What is the battery life and autonomy of the system? How accurate is remote reading? Moreover, how are the readings displayed through the MARS application?

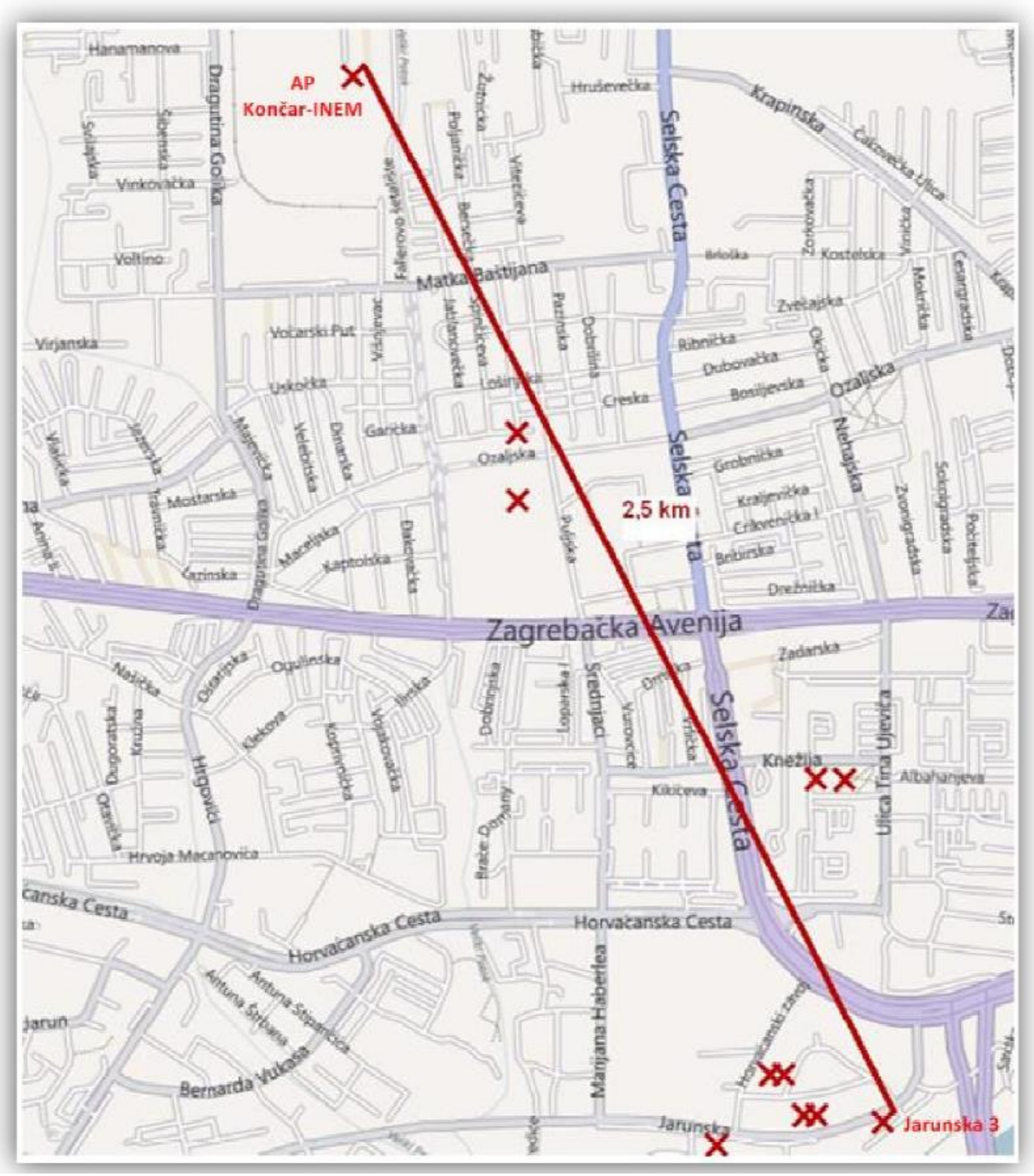


Figure 4.9: Spatial layout of selected locations 1. Pilot project Knežija-Jarun

The initial measurements conducted in March and April 2012 at the specified locations indicated that the installation of non-return valves was essential at most sites to prevent backflow and ensure accurate readings. This requirement extended the timeline, resulting in accuracy monitoring commencing on May 23, 2012. Employees from VIO manually checked the water meter readings multiple times per month and compared them with the data in MARS.

In the first pilot, the signal was relayed directly from the shaft to the concentrator at the top of the building, which imposed a battery load 24 times greater than usual to evaluate the system's autonomy, robustness, and functionality at the signal's limits. The registrar and concentrator in this pilot operated using the IEEE 802.15.4 standard at 868 MHz (ZigBee protocol) for local network formation. Long-range communication was accomplished at the concentrator using 2.4 GHz ULP technology.

An analysis of results from the Knežija - Jarun pilot project highlighted issues with water backflow at some measurement sites, resulting in so-called "false" impulses. These false impulses could mirror the duration of actual impulses, leading the registrar to record them, which caused measurement inaccuracies mistakenly. This issue was addressed by installing non-return valves or employing water meters with inductive impulse transmitters capable of detecting the direction of water flow (e.g., Elster PR7/PR6) or using ultrasonic meters that also discern flow direction.

Inaccurate impulse outputs from IKOM water meters were resolved using meters manufactured after 2010. It is crucial to ensure proper contact with the reed disk (the red plastic spacer may obstruct correct contact), verify the thickness of the glass (old, unverified glass should be avoided during calibration), and avoid using impulse transmitters made prior to 2010.

For Woltmann water meters, false impulses are rare, except in cases of mechanical damage. An advanced algorithm developed by Končar INEM detects and mitigates most false impulses, which may occur infrequently due to vibrations, sudden pressure fluctuations, or consumption variations. However, for these and similar types of meters, there is no algorithm capable of eliminating measurement error, as it is impossible to differentiate between a false impulse and a real one if they share the same duration without the capability to detect the direction of rotation.

In the pilot program, battery consumption increased significantly due to a load that was 24 times higher than usual. The system was set to transmit data 24 times a day—every hour, sending a package of 15-minute readings—instead of the planned once-daily transmission for hourly data. As a result, the registrars operated with 24 times the usual load in terms of battery usage, meaning that a month of pilot operation was equivalent to 24 months of typical use. Some of the registrars in the water meters operated from February to the end of July without any errors or interruptions, demonstrating that the battery could potentially last over ten years.

- Register of the Recorder

The tested system exhibited excellent performance when transmitting signals from the shaft, particularly within buildings. Specific sites operated near the edge of the range (e.g., Jarunska 5; Knežija 3), revealing a lack of desired stability and excessive battery consumption due to frequent transmissions. Such operating conditions should be avoided in the future, prompting the planned introduction of a repeater (signal booster) to enhance the signal between the recorder and the concentrator. The recorders (ZigBee, IEEE 802.15.4) deployed in this pilot demonstrated a communication range of 200m from the shaft or over 1km with line-of-sight.

- Accuracy of Measurement

The recorder's acceptance and reading of impulses, along with their transmission via the concentrator to the access point and visualization in the MARS application, occurred without error. Nevertheless, issues arose with certain meters that failed to provide accurate impulses (reed impulse sensors). These problems were addressed as outlined above, yielding excellent results, except for the location Fallerovo šetalište 22, where the maximum error reached 0.13%, which remains significantly below the accuracy tolerance of the water meter (2%).

- MARS Application

There were issues in reading data in group mode (multiple channels simultaneously - combined water meters), leading to the interpolation of missing data (identified in MARS as interpolated decimals). Such data were sometimes incorrectly recorded as read data, while they do not exist in terms of "all data" (such as in cases where the battery was depleted). According to the State Bureau of Metrology regulations regarding water meters and consumption measurement, valid data are those read from a calibrated water meter's dial. Consequently, the application must be modified to enable reconciliation between the data in MARS and the water meter dial readings during regular maintenance, such as when replacing water meters for calibration. Additionally, the application requires enhancement to support the automatic billing system VIO. The primary data within this application should include the measurement site code alongside the customer code, enabling the transfer of the water meter status for the last day of the month to the VIO Billing system (UPN).

- Operation of the Concentrator

The concentrator operated reliably and stably. The only exception was a short-term, repeated power outage (220V) that briefly disrupted the system.

Following the interference, the system demonstrated its ability to recover and proved robust, resolving the previously mentioned issue. The concentrator has an established range of up to 3,800 meters in urban areas without optical visibility and up to 10 kilometers with optical visibility.

- Access Point (AP) Operations:

The access points are operating stably, with no complaints reported. The range is deemed satisfactory, confirmed during the pilot project at approximately 2,500 meters without optical visibility in an urban setting, using an antenna on the 4th floor. To achieve a range exceeding 5 kilometers under normal conditions, it is essential to locate installations at higher altitudes, with water tanks owned by ViO identified as suitable sites for antenna installation shortly.

- Concentrator Installation:

The requirement for 220V power complicates challenges related to the placement of the concentrator, including obtaining permits. This issue needs to be addressed by mandating property owners, as outlined in the General and Technical Conditions for installing water meters, to facilitate the installation of AWMR equipment. The power consumption of these concentrators is minimal.

- Conclusions and Planned Improvements for AWMR Equipment:

1. Develop a more energy-efficient impulse counting system to enhance the battery life of the recorder.
2. Create a more robust communication channel to improve performance on the signal edge.
3. Introduce a repeater as a signal booster when necessary (e.g., on multiple floors or greater distances from the concentrator).
4. Utilize properties owned by VIO (approximately 300 sites) for access point installations, focusing on water tanks and secure facilities at elevated locations.
5. Discontinue impulse transmitters with reed relays favoring inductive transmitters or ultrasonic water meters.
6. Develop support for ultrasonic water meters.
7. Enhance the configuration interface and service tools (software support) for field operations.
8. Develop support for the M-BUS system.
9. Create a multi-layered concentrator (ZigBee/M-Bus/ULP/GSM/Optics/Ethernet).
10. Integrate the MARS water meter reading system with the automatic water billing (Billing ViO: UPN).
11. Conduct a second pilot project within an older residential building with internal water meters in the apartments.
12. Outline a strategy for developing a comprehensive network and the potential integration with the SDM system (Optical et al. ZGH).

4.8.2. Pilot projekt 2

The second pilot project was conducted in an older residential building in the Maksimir district, specifically at Prilaz Slave Raškaj 9 (from now on referred to as PSR9). This pilot marked the first instance where a building with separate units was directly connected to its billing system (RISOV-VIO). The activities for this pilot began in June 2012, when an initial information meeting was held with a representative of the tenants at the specified address. All tenants agreed to install internal water meters, a fundamental requirement for participating in the pilot, according to the applicable General and Technical Conditions of ViO. The building's layout, featuring two verticals with six apartments connected to each, also meant that only one water meter per apartment was necessary. According to the schematic representation provided, a new main water meter, TK equipment, and valve internal water meters were installed in the building.

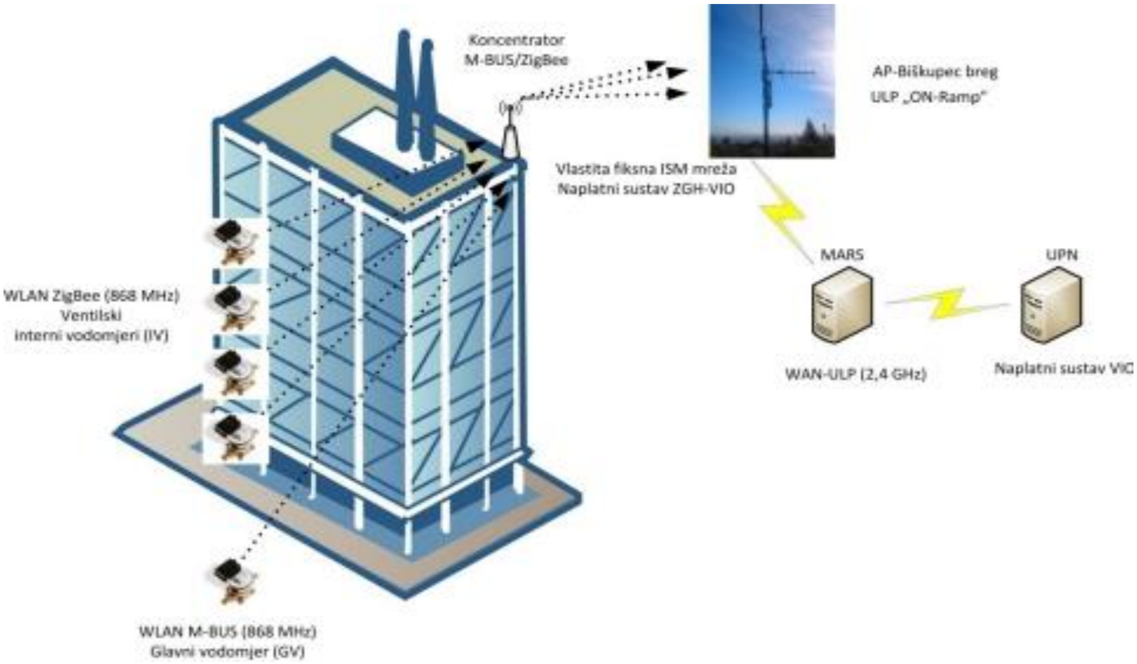


Figure 4.10: Schematic representation 2. Pilot project PSR9

The building comprises 12 apartments and one standard room where water is utilized. In early September, multiple-jet water meters with inductive pulse transmitters, specifically the Sensus Muk model HV, 30, 1.5 m^3/h, class B accuracy, were installed in these locations. An ultrasonic water meter with a pulse output, model Multical 62, 16 m^3/h, DN50, L=270 mm, replaced the main water meter. As part of this pilot project, it was necessary to identify a new access point location to provide coverage for the residential building within pilot PSR9.

The requirements for the new access point site included:

I. Situated on VIO-owned property at a higher elevation with an "open" view of the city
II. Capable of achieving a more excellent range and covering a larger area than the initial pilot project

Upon analyzing the spatial layout of VIO facilities, the water reservoir Biškupec Breg was selected as the optimal site for the new access point. It is located approximately 5.2 km (line of sight) from the residential building in PSR9, at an altitude of 344 m. An ADSL connection for this access point was established at the end of October, and it became operational at the beginning of November.

Signal range assessments exceeded expectations, demonstrating excellent coverage in the eastern and southeastern regions of the city. The signal was confirmed in Jelkovcu to the east, on the Street of the Croatian Brotherhood Community to the west, and south to Mičevac on the southern bypass, covering approximately 10.5 km. Concurrently with the setup of the access point at Biškupec Breg, efforts were made to connect the MARS-RISOV bases, culminating in a successful link established in January.

Simultaneously, TK equipment was installed within the building. Unlike the first pilot, repeaters were also introduced to prevent operating at the signal's edge and prolong battery life. A local area network (LAN) was established adhering to the IEEE802.15.4 (ZigBee) standard, complete with registrars, repeaters, and a concentrator linked to the ULP long-range network (WAN). The concentrator transmits the data collected from the local network to the access point at Biškupec Breg, which is forwarded via ADSL to the MARS server at Faller's promenade 22 (Končar-INEM). Subsequently, this data and readings are sent to the RISOV-VIO billing system. The first readings from this system were recorded in January 2013, marking the commencement of automatic billing for residents based on readings from the AWMR system. This document concludes with an analysis of the results derived from the PSR9 Pilot project.

From January onward, MARS readings have been supplemented with manual readings conducted by resident representatives for apartments and VIO staff for the main water meter. It has been confirmed that there are no discrepancies; the data obtained from MARS aligns with the manual readings. The bills issued under this pilot project thus far are based on the actual consumption recorded on the internal water meter, incorporating an additional adjustment derived from the difference between recorded readings and the total of all internal water meter readings. This adjustment is allocated according to the share in UZP, reflecting everyday consumption based on living area. Water usage in common areas is financed from a typical reserve.

The access point exhibited excellent signal coverage, although three minor communication interruptions occurred. The first interruption occurred in early May, reportedly due to a lightning strike that affected the antenna pole; this caused damage to contacts in the phone and network router slots, while other AWMR equipment remained intact as the pole was grounded. The router and surge protection were replaced to prevent future outages. The second and third interruptions happened in mid-May and July and were resolved by resetting the router.

Previous irregular readings led to significant fluctuations in bill amounts. In September, internal water meters were installed, initially requiring manual readings from September to January, as indicated in the diagram. Subsequently, readings began to come automatically through the AWMR network, resulting in an approximately 25% reduction in water consumption post-AWMR implementation.

- Conclusions on the Pilot Project:

I. The consent for equipment installation must be addressed, necessitating amendments to the General and Technical Conditions.
II. A mixed billing system should be developed for residential buildings lacking a water meter in each apartment.
III. Surge protection needs to be installed at each access point.
IV. As the installation costs for this system significantly affect residents, efforts should be made to secure a lower purchase price for water meters through public procurement based on quantity.
V. Valve water meters have been effective; however, their maintenance is relatively costly, with service during calibration accounting for 30-40% of the water meter price.

4.8.3. Pilot projekt 3

The third pilot project was carried out in the subsidiaries of Zagrebački Holding, Čistoća, and VIO, encompassing three measurement points located on Radnička Cesta and Folnegovićeva Street. In February 2013, the existing central water meters were replaced with Elster-type combined water meters featuring PR6 and PR7 inductive pulse transmitters. Shortly after that, the installation of AWMR equipment commenced; for VIO, one registrar was placed in the maintenance hole along with one concentrator in the administration building, while Čistoća required two registrars, one concentrator, and one repeater. The registrars are dual channels, allowing them to collect pulses from small and large water meters. By early March, the system was fully operational, and since February, billing for these locations has been based on readings obtained from the AWMR system.

The access point is situated at Biškupec Breg, like the previous pilot, and is approximately 6.5 km from the concentrator in the administration building at Folnegovićeva 1.

Analysis of the results shows that since the access point in this pilot is the same as in the second pilot, outages at Biškupec Breg affected readings in the Čistoća pilot, highlighting effective continuous communication over 6.5 km. During the outages at Biškupec Breg, some challenges were encountered when reconnecting the telecommunications equipment after the connection loss between the concentrator and the access point. This issue was addressed in the latest firmware version.

4.8.4. Pilot projekt 4

For the fourth pilot project, the largest residential complex in the City of Zagreb, known as 'Mamutica,' was chosen. The Mamutica complex is situated in Novi Zagreb within the Travno district and, along with 'Mala Mamutica,' includes 13 entrances, each containing around 140 separate units, resulting in approximately 1,800 apartments and about 5,500 residents.

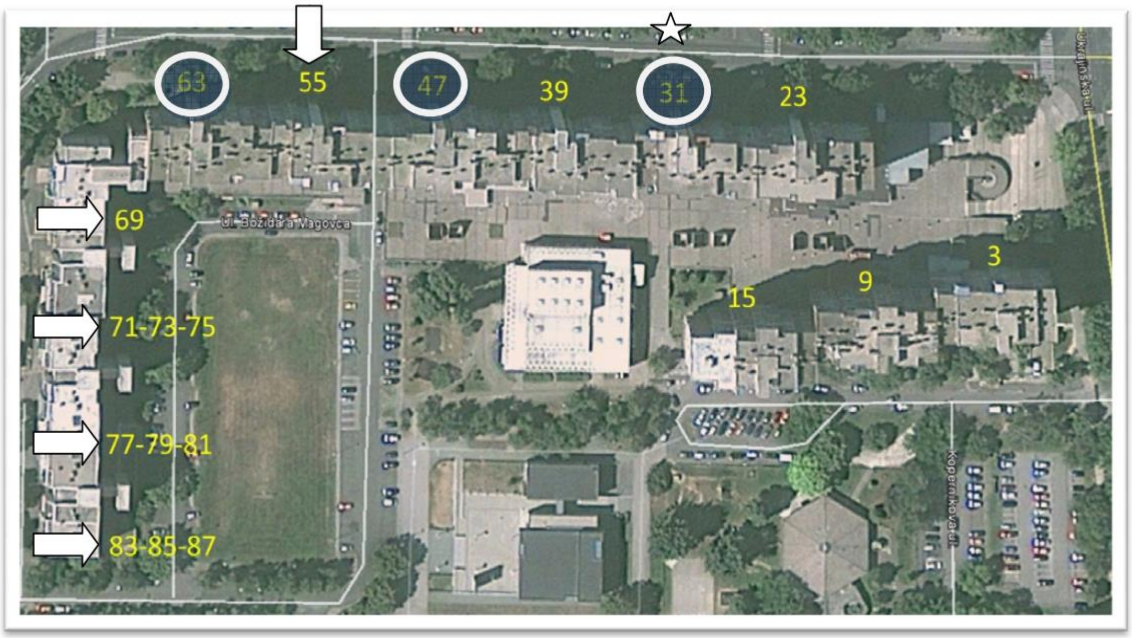


Figure 4.11: Display of the Mamutica Complex

Activities related to this pilot project commenced in early 2013 when an agreement was reached with the representatives of the co-owners and residents of all entries to prioritize entry 63. After completing this entry, the subsequent ones will be addressed in sequence. In March, the water meter was moved from the water meter shaft to the hydrophore system room, where an ultrasonic water meter, DN50, type Multical 62, was installed, mirroring the setup from the pilot project PSR9. Unlike the second pilot project that employed IEEE 802.15.4 technology for the local network, the implementation in Mamutica will utilize Wireless M-Bus technology. A notable challenge at this site is the configuration of four vertical shafts in each apartment, comprising two for hot water and two for cold water, necessitating the installation of four water meters. In early June, ultrasonic internal water meters of type Hydrus, DN20, Class D accuracy with Wireless M-Bus radio modules, were installed for the residents' representatives in that entry.

Figure 4.12: Internal UZV water meters

Further actions concerning this pilot project were conducted during or after the study's writing. It is essential to highlight that, due to the building's advantageous spatial location and its height of 20 floors, there are plans to install 3-4 access points on top of Mamutica. The residents' representatives have approved the installation of the antenna, ORW, and ADSL connection, and the activities have begun.

The evaluation of the Mamutica Pilot Project Measurements results has confirmed a satisfactory range for the Wireless M-Bus signal emitted by Hydrus's water meter. This enables the installation of repeaters on every second or third floor of the building. Strategic access points at this location are expected to effectively cover all of Novi Zagreb, including the eastern and central parts of the city. While the stainless-steel water meter cabinet slightly attenuates the signal, it remains acceptable from both technical and aesthetic perspectives; a plastic cabinet alternative is also feasible. Due to the investment volume, challenges have emerged in securing contracts to install internal water meters with residents. To address this, a payment model has been developed, offering installment options over 12, 24, or 36 months, which will facilitate a significant number of residents in installing internal water meters.

4.8.5. Pilot projekt 5

The pilot project is set to be carried out in collaboration with the Zagreb Holding Branch, Digital City, in the newly constructed Vrbani 3 settlement. Specifically, the Digital City Branch of Zagreb Holding is working on the SDM (Fiber et al.) project, which aims to provide fiber optic connections to every apartment based on the FTTH (Fiber to the Home) principle, ensuring each apartment has its optical fiber. This project aligns seamlessly with the AWMR project by providing a single optical fiber for the concentrator, which connects to the fiber optics to transmit building readings to the MARS server. It is essential to mention that the entire settlement is already equipped with secondary water meters utilizing wired M-Bus technology, allowing the wired M-Bus controller device to easily connect to the concentrator, with collected readings being transmitted via the optical network to MARS.

Figure 4.13**:** Spatial representation of the covered area in the Vrbani 3 SDM project.

4.9. Development and implementation of a new system for remote reading of water meters – AWMR

AWMR, which stands for Automatic Water Meter Reading, is a sophisticated, innovative network designed to read water meters and automated billing remotely. The VIO subsidiary developed it between 2012 and 2013 and has undergone testing through various pilot projects. The core concept of this network is depicted in the image below. The primary components of the network include:

I. Local networks (HAN/LAN) for buildings, industrial sites, or city districts,
II. A remote network (WAN) featuring access points (AP) and a ULP gateway,
III. A water meter reading system (MARS),
IV. A billing system (UPN; E-UPN),
V. A user system (MOJ-VIO, ISGE, and other front-end user interfaces and systems).

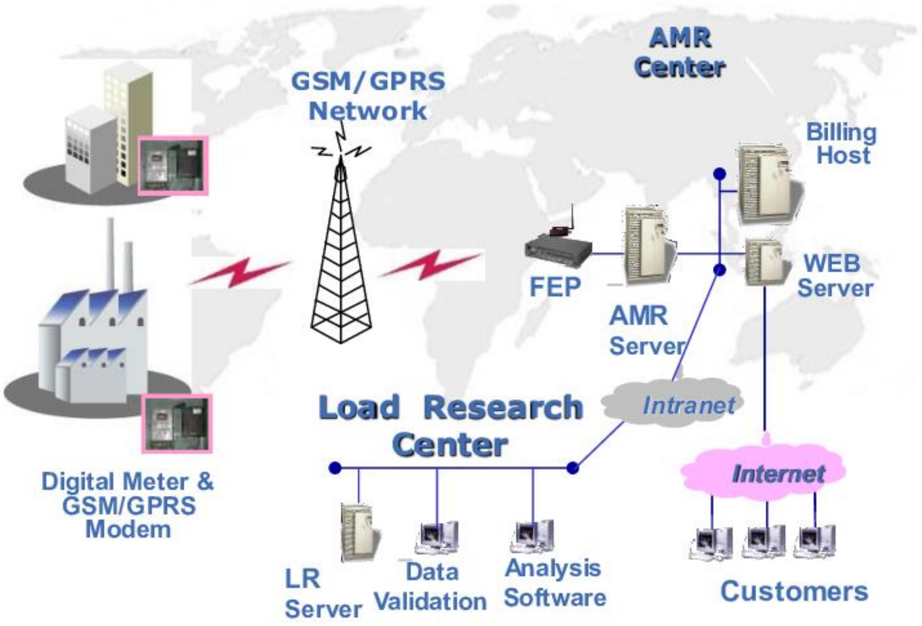


Figure 4.14: The fundamental concept of the intelligent AMR network for reading water meters

The primary objective of this network is to facilitate the automatic connection of VIO users with the water meter reading system. This allows for real-time monitoring of water consumption and billing based on actual usage, eliminating the need for estimates and calculations related to shared consumption. Achieving this goal significantly reduces water losses, leading to substantial savings.

The AWMR network has been designed to have high data acceptance and transmission flexibility. This flexibility is accomplished through modular data concentrators that adapt to field conditions, enabling communication via Ethernet, optical fiber (SDM), mobile networks (GPRS), or a proprietary wireless network (ULP). This approach offers:

I. Excellent coverage in remote locations such as basements and maintenance holes
II. Targeted coverage in specific areas using a long-range wireless network
III. Minimal monthly costs for data traffic or licenses for water meter readings

At the core of the AWMR advanced measurement system is the Ultra Link Processing (ULP) technology. ULP employs an advanced algorithm to package and extract valuable data from signals below the noise level, facilitating establishing a long-range wireless radio frequency network (WAN) with exceptional coverage. This network can achieve over 10 km radius ranges in open spaces, utilizing the unlicensed 2.4 GHz frequency band. Access Points are set up on VIO facilities at elevated locations, such as water reservoirs, allowing for gradual expansion into new areas of the distribution network.

In urban settings such as the City of Zagreb, a local wireless network (LAN/HAN) operating at 868 MHz is essential, along with the widespread IEEE 802.15.4/ZigBee standard. This is particularly important for accessing meters in water meter chambers and other challenging locations, as it ensures adequate signal penetration through walls and obstacles. Critical components in the development of the advanced measurement system include:

I. LAN/HAN based on the IEEE 802.15.4/ZigBee standard
II. WAN powered by the OnRamp ULP solution
III. Web-based AMR software

This system architecture addresses challenges related to complex and costly installations, eliminates fixed monthly expenses or frequency band leasing, and boasts meager maintenance costs. The AWMR system integrates a remote reading solution developed by Končar – electronics and informatics d.d. and is part of a comprehensive system. AWMR is adaptable, allowing for the formation of local networks with various technologies and enabling the integration of a diverse range of water meters with radio output into the network.

It is also versatile in transmitting readings through a remote network, effectively addressing the specific needs of various locations (such as signal transmission issues from water meter wells, basements, etc.). Local networks operate within the 868 MHz frequency range, which supports critical European standards (Wireless et al. 802.15.4), integrates existing M-Bus solutions, and simplifies the reading of current water meters with pulse outputs.

This type of local network is established using a combination of a Data Concentrator, Repeater, and Data Logger. The Data Logger converts the impulses from the water meter into digital data representing the water meter reading. When combined with the repeater (if necessary), these devices create the local network. The Data Concentrator serves as the coordinator for this network, prompting the devices within it to transmit the collected readings through one of the available connections to MARS and subsequently to the UPN and the MOJ VIO internet application.

4.10. Basic components of the local AWMR network (LAN/HAN)

The fundamental elements of the local AWMR network are:

I. Water meter equipped with an impulse transmitter (or integrated versions with a radio module)
II. Register (or data collection device in conjunction with a water meter featuring an impulse transmitter)
III. Repeater (or signal repeater)
IV. Concentrator (or remote station)

- Impulse transmitter

The impulse transmitter is a device that provides measurement data for data collection systems. It is attached to the water meter and interrupts the circuit for every 100 liters (0.1 m^3) of water used, with exceptions for 10 or 1000 liters. The same principle applies to other energy sources.

- Registrator

The data collection device, the registrar, is situated directly adjacent to the water meter, with a maximum distance of 10 meters. It is connected via a conductor that transmits consumption data, such as impulses or measurement readings. This device is capable of reading up to four water meters simultaneously. It operates on battery power, has a two-year lifespan, and includes a microcontroller and a radio frequency (RF) transceiver. The microcontroller counts the impulses and stores the total in memory. The RF transceiver remains in 'sleep' mode and transmits consumption data to the remote station on a set schedule. The data collection device can also receive data from water meters and is equipped with a built-in Wireless M-bus module, allowing for wireless data transmission.

- Repeater

A repeater is a device that functions as a communication bridge. It operates on batteries and includes a microcontroller and a radio frequency (RF) transceiver. The RF transceiver remains in "sleep" mode, activating at set intervals to gather consumption data from connected devices via a wireless local area network. It then transmits this data to a data concentrator or an advanced repeater through the same network.

- Concentrator

A concentrator or remote station device within a local area network (LAN) bridges a vast area network (WAN). Powered by the network, it features a microcontroller and two transceivers. The first transceiver facilitates establishing and managing the local short-range network, to which devices for data collection across the facility (or specific sections) are connected. Within this network, the concentrator functions as the coordinator, gathering packets from all data collection devices (registrars) and forwarding them to the central application.

Additionally, the remote station enables the reception and transmission of messages from other remote stations (coordinators) that relay data from more distant water meters to the central remote station, especially in scenarios where the central station is out of range. This setup allows the remote station to connect with a hundred or more data collection devices (registrars). The number of remote stations (concentrators) may vary based on the chosen frequency and permissible transmitter power. Each micro-location should host at least one remote station, while the total number of remote stations should remain significantly lower than the number of installed water meters.

The remote station must communicate with the Central application of the AWMR, facilitating the transfer of all pertinent measurement and process data, including:

I. Consumption data for individual energy sources, complete with timestamps, tariffs, and relevant billing information.
II. A unique device address within the communication system.
III. Battery voltage for battery-powered devices.
IV. A signal quality indicator for wireless networks (LQI) devices.
V. The connection method to superior devices (data path).
VI. Transmission of alarm and diagnostic information.

Furthermore, upon request, system upgrades and the transfer of supplementary data concerning monitoring water meter status (such as alerts for unauthorized removal of the pulse transmitter, etc.) need to be activated. This should be achieved through a software update of the data collection module from the water meters.

4.11. Long-distance wireless network

Various communication paths can be employed for implementing long-range networks, including GPRS, Ethernet, or OnRamp Wireless ULP communication. This flexibility enables easy modifications due to the modular concentration. In addition to these standard communication methods, the OnRamp Wireless Ultra-Link Processing (ULP) module facilitates communication between distributed devices and the central system, where data is gathered via the OnRamp wireless network. The parent side utilizes an Access Point (AP) device connected to the Gateway (GW) computer via Ethernet, while the child side employs the eNode module. The OnRamp ULP system operates on a star topology with alternating bidirectional (half-duplex) communication. Access points (AP) connect directly with nodes in a single hop. ULP supports signal reception below the noise level, with sensitivity as low as -142 dBm, enabling device setups that communicate over long distances in unlicensed frequency bands, even amidst potential interference and challenging locations for remote devices. The access point network can effortlessly provide redundant signal coverage across extensive areas, having demonstrated a range of over 15 km in license-free regions in Zagreb.

- Access point

The access point functions as a device that gathers data using a concentrator. The data the access point collects is transmitted through the Internet connection to the Central Application. In Figure 5-2, the initial access point, Biškupec Breg, is illustrated as part of the AWMR pilot projects from the end of 2012.

Figure 4.15: Access point at the water reservoir VIO - Water reservoir Biškupec Breg

4.12. Central system for reading water meters

The central system for reading water meters comprises network equipment, servers, and software that facilitates the collection of reading data from remote networks. This includes storage, processing, visualization, and transmission of consumption data, along with all other requirements of the VIO (such as user, measuring device, and billing system management). Furthermore, it allows for integration with other systems as necessary for the VIO.

The system must support data reception from the access point via specified TCP/IP packets. Each measuring point's packets should contain the following information:

I. Consumption data for individual energy sources, along with corresponding timestamps, tariffs, and any other relevant billing information
II. A unique device address within the communication system

III. Identification (code) for the measuring point and VIO customer
IV. Battery voltage for battery-operated devices
V. Signal quality indicator for devices using a wireless network (LQI)
VI. Connection method to superior devices (data path)
VII. Transfer of alarms and diagnostic information

The application should also allow system upgrades to monitor the condition of water meters (e.g., alerts for unauthorized movement of the pulse transmitter) and manage control elements via data collection devices. The application must include the following modules:

I. Report generation
II. User and client management
III. Export to the billing system
IV. Alarms and events
V. Data collection
VI. Data management
VII. Data Overview
VIII. Data Integrity

The application must facilitate data transfer and synchronization with the VIO-UPN billing system to enable the automatic generation of monthly invoices.

4.13. Application MARS

Končar MARS serves as the core of the AWMR centralized water meter reading system and functions as its programming backbone. This software is primarily designed to gather and store measurement data, facilitating subsequent processing, display, report generation, and integration with other systems (such as web services) and billing applications.

The Končar MARS system comprises both server and client components. Its server architecture is built on extensive experience in the field, incorporating proprietary KONČAR solutions alongside those from other manufacturers. This design enables data collection from diverse devices utilizing various communication technologies. The system supports multiple communication protocols, notably ULP, Ethernet, GPRS, RS232, and RS485. Each protocol utilized by Končar MARS is implemented as a distinct service, with a unique MARS interface for each. This structure facilitates rapid upgrades and the incorporation of additional technologies, allowing the MARS server to function as a bridge between various data sources and the user application for data processing and visualization.

The data collection process is largely invisible to the end user, who interacts exclusively with the client with part of the application accessible via a standard web browser. A vital feature of the Končar MARS system is accessing data from any computer with internet connectivity. Upon logging in, users gain access to a comprehensive suite of tools for system analysis and management.

The functionalities of the Končar MARS application are categorized into different modules, divided into three main groups tailored for various user types. The first group pertains to the physical elements of the system—such as meters, gauges, sensors, and transformer stations—as well as the quality of the communication links with these devices. Critical modules in this group include the Data Collection Module and the Data Integrity Module. The Data Collection Module integrates physical data sources (like meters and sensors) into the system. At the same time, the Data Integrity Module keeps users informed about any issues that may arise during measurement or data retrieval.

The second set of modules pertains to data's logical organization and visualization. This set includes the Logical Management Module, enabling users to arrange system elements based on their preferred logical hierarchy and criteria, such as physical location or equipment ownership.

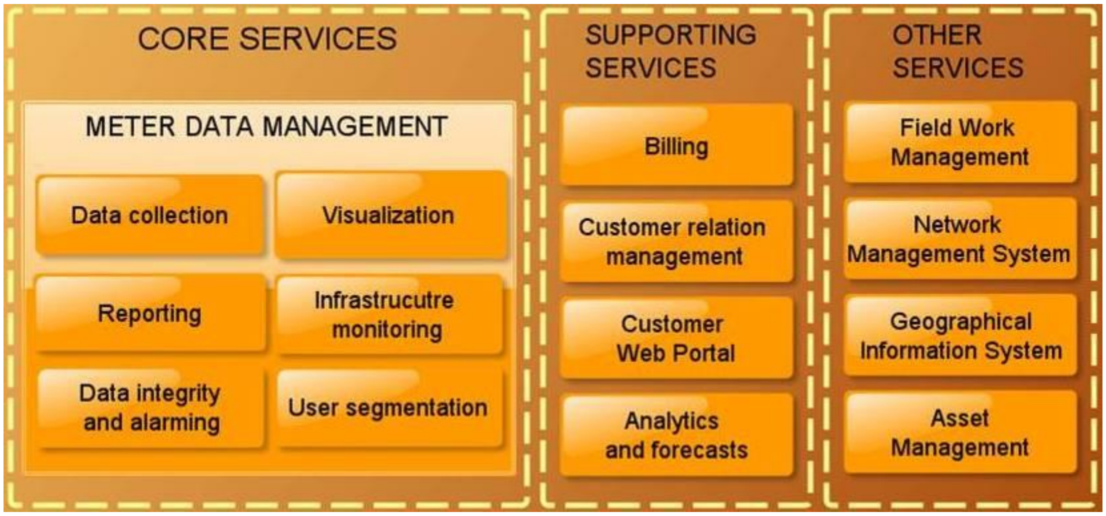


Figure 4.16: Modules of the MARS application

4.14. Planning the long-distance network (ULP)

Effective long-range network planning ensures adequate coverage in specific areas, such as the City of Zagreb, while maintaining a satisfactory ULP signal for data transmission. The process unfolds in several key phases:

I. **Selection of Potential Installation Points**: It is crucial to identify locations that offer available power supplies and internet connectivity and secure the property owner's consent for the installation. The installation should occur at the highest points of the building, where ORW and GPS antennas and access points will be mounted on suitable poles.
II. **Development of a Preliminary Model**: This model is conceived using data from publicly accessible terrain maps, providing a basis for cost estimation and size expectations. Results can vary significantly due to simplified models with limited input data, and installation points are typically chosen preliminarily.
III. **Detailed Network Planning**: This complex phase employs specialized software and hardware tools, requiring extensive input data. It follows the preliminary model's creation and necessitates knowledge about:
    - Characteristics of receiving and transmitting powers
    - Types of antennas and their radiation patterns
    - Types of receiving antennas and devices
    - Exact heights for antenna placements
    - Losses in cables and connectors
    - Attenuation on the receiving end

This planning phase also employs more accurate geographical models. In this second modeling phase, initial results are compared against field-collected data through measurements, allowing for adjustments for increased accuracy and subsequent verification.

I. Validation: After the access points are installed, a terrain recording plan is developed, followed by data collection according to this plan. This data finalizes the model, facilitating signal strength calculation at specific locations and enabling detailed planning for Concentrator installations.

During the first three pilot projects, a site was chosen for access point installation at the Biškupec Breg water reservoir, yielding outstanding results that exceeded those predicted by the preliminary model. Specifically, the outcomes illustrated below would have necessitated a 20m elevation in the antenna pole, yet by installing it on an existing pole, we achieved impressive results, significantly surpassing initial expectations.

The legend in the upper left corner indicates the significance of the colors. The percentages reflect signal coverage, assuming no attenuation at the receiving end, with the Concentrator positioned at ground level.

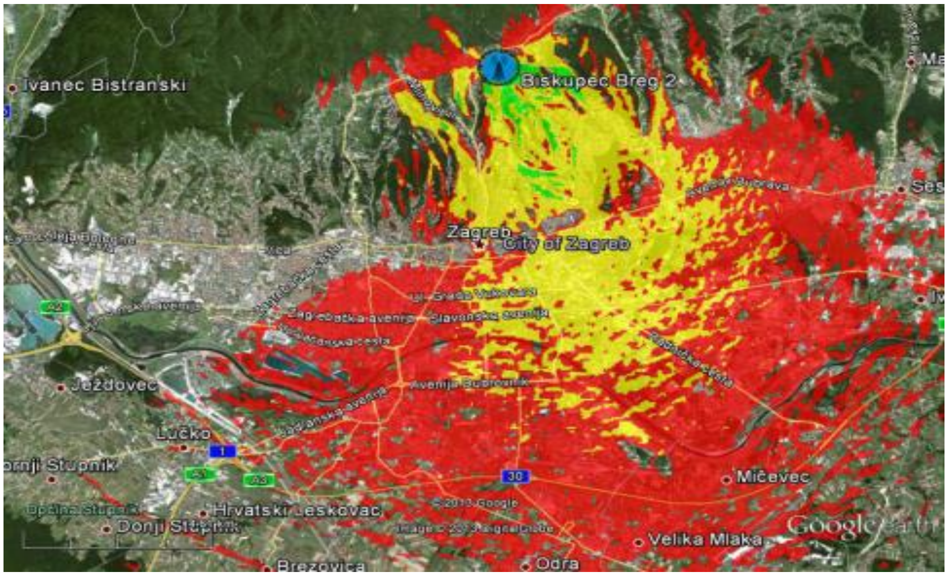


Figure 4.17: Spread of RF signal ULP from AP-Biškupec Breg (ON-Ramp mathematical model)

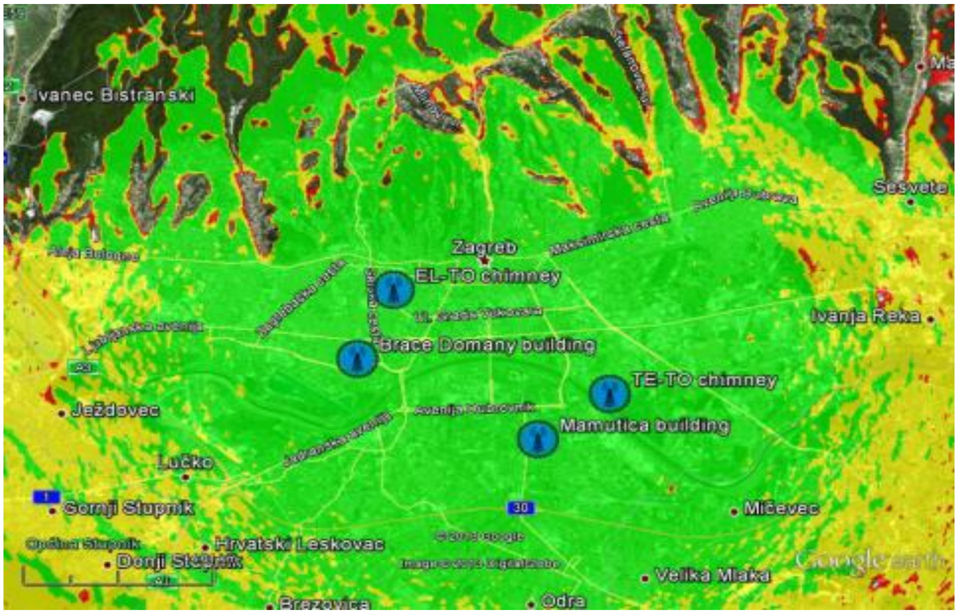


Figure 4.18: Planning APs ULP for the City of Zagreb (ON-Ramp mathematical model)

Preliminary findings suggest that sufficient coverage could be attained by placing access points (APs) at four strategically selected high locations in the city center. Due to spectrum usage limitations, each location will need four APs and antennas with a minimum gain of 17 dB, and a horizontal directivity of 90° must be utilized.

4.15. Integration of AWMR with SDM

The Zagreb Digital City Branch initiated a pilot project to implement the optical distribution network (ODN) in the Vrbani III settlement following a decision made by the President of the Management Board of Zagrebački Holding on March 8, 2013. The City Assembly of the City of Zagreb supported this project with a conclusion adopted during the 47th session on February 21, 2013. Among the project's team members is a VIO Branch representative interested in integrating the ODN with the AWMR network. At the Vrbani III site, local networks (LAN) have already been set up in residential buildings to facilitate water meter reading through the M-BUS system. The objective is to link these local networks with the ODN to form a complete AWMR network, which will connect to the remote network (WAN) and the VIO billing system.

- Basic about the project SDM-FFTH „Vrbani III“

The introductory section outlines that, according to the Project Task of the Zagreb Digital City Branch, the current investment landscape in Zagreb reveals a notable decline in the development of electronic communication fiber optic infrastructure. Investors are struggling to discern profitability or confront barriers that inhibit investment opportunities. While enjoying substantial profits from their established networks, traditional telecommunications operators lack the motivation to invest further despite rising demands for higher-quality services from their customers. Future development primarily relies on increased competition, which has yet to solidify, or intervention from external sources.

Continuing to develop the access network solely based on copper infrastructure would yield several adverse outcomes: I. a failure to provide new services or limited capacity to serve a small user base, II. a decline in service quality due to the high density of ADSL users and a rise in disruptions, III. escalated operational maintenance costs.

Data collected by the Zagreb Digital City Branch at the end of 2010 and the beginning of 2011 indicates that considering broadband access as having download speeds exceeding 144 kbit/s, the user connection methods in Croatia are as follows: I. xDSL access via copper distribution – 66.85%, II. mobile network access (EDGE, UMTS, HSDPA) – 25.55%, III. stationary wireless access (Homebox et al.) – 1.84%, IV. Access via cable television networks is 5.35%, V. access through leased lines, fiber optic cables, fiber optic threads (FTTH), and satellite connections is 0.41%.

Analysis shows that service users predominantly seek: I. higher transmission speeds, II. improved security and service quality, III. flexibility in accessing the network, and IV. the freedom to choose their service provider.

Passive access points for the optical network are primarily based on implementing fiber optic threads directly into user facilities (FTTH). Fiber optic networks possess several advantages: I. resistance to weather and electromagnetic interference, II. They have proven to be highly secure and reliable. III. significantly fewer interventions than copper cables, IV. more straightforward construction, V. much higher energy efficiency, and V.I. a lower environmental impact, including reduced CO2 emissions.

The key objectives of the SDM for the City of Zagreb, as per the outlined concept, are I. the construction of the SDM across all 17 city districts: 200,000 connections over six years, II. the establishment of an open access model for physical infrastructure: offering transparent, non-discriminatory conditions to all operators, ensuring access to all potential end users, III. laying the infrastructural groundwork for smart city and smart grid solutions (electricity, water, gas, e-services, etc.), and IV. alignment with the goals of the EU Digital Agenda.

4.16. Installation plan for AWMR equipment

The remote AWMR network system is designed around its own ISM network, which aims to cover a significant portion of the service area in the City of Zagreb. Local water meter networks (LAN) lacking their remote network (WAN/ULP) can connect to the remote system through alternative access methods for the water meter reading system. The system's capabilities hinge on the modular design of the AWMR concentrator, which accommodates various remote technologies, generally including ULP, GSM/GPRS, Ethernet, and SDM access is also considered. The choice of the remote system may vary based on the development pace of the AWMR and SDM networks. However, future decisions regarding connection will largely depend on the operator's service costs, which significantly impact data distribution for water meter readings (from DČ to Gateway MARS). The designated area for constructing the AWMR network within the SDM at the Vrbani III location is illustrated in Figure 6-3. This area features buildings with local M-BUS (wired) systems for remote water meter readings during construction. An analysis of these systems confirms their operational status and good maintenance. Given this context, a customized concentrator is planned to connect to the AWMR network, with its receiving end linked to the RS 232 output of the M-BUS controller device, while the front end will connect to the optical network. As such, the optical connection and the concentrator must be established adjacent to the M-BUS equipment cabinet.

4.17. Standards and legal acts related to water meters

Nine international water meter standards outline terminology, their use specifications, maintenance requirements, and more. These standards can be found in various documents that share closely aligned requirements. Essential international standards include:

- International Organization of Legal Metrology (OIML): OIML R49 - Water meters intended for measuring cold and hot potable water.
- International Organization for Standardization (ISO): ISO 4064 - Water flow measurement in fully charged closed conduits – Meters for cold and hot potable water.
- European Union Standard: EN 14154 - Water meters, responding to Directive 2004/22/EC, known as the Measurement Instruments Directive (MID).

The Croatian Institute for Standardization has validated the European standard EN 14154 as applicable for Croatia, designating it as HRN EN 14154. This incorporation aligns with the MID requirements outlined in the Regulation on technical and metrological requirements for measuring instruments (NN 85/13).

The regulation establishes the technical and metrological criteria measuring instruments and systems must be fulfilled to market or utilize. It also delineates the rights and obligations of entities that distribute and employ these measuring instruments, procedures for assessing their compliance, criteria for appointing notified bodies, documentation requirements for competent authorities, instrument marking methods, and oversight for adherence to established requirements.

Instruments in use, when the Regulation is enacted and possessing valid initial verification, can be submitted for regular or extraordinary verification, provided they comply with the original regulations under which they were utilized. Additionally, instruments with valid type approval decisions at the Regulation's enactment can remain on the market and be used within Croatia until the type of approval expires or by October 30, 2016 (ten years after introducing new MID provisions). The new MID requirements have been practical since October 30, 2006, replacing the earlier Directive 75/33/EEC.

These MID requirements detail the construction standards for measuring instruments, compliance marking procedures, and associated legal processes for assessing conformity before calibration. Outdated standards, markings, and designations must be updated to conform with the new MID compliance terminology previously labeled under EEC directives. Compliance with MID is evaluated, with governmental oversight provided by the State Office for Metrology, which supervises the conformity assessment process per the Law on Technical Requirements for Products and Conformity Assessment (NN 80/13).

Chapter V:
DISCUSSION

5.1. Design of the WALEGRIN 4.0 model

The model’s name is derived from the initial letters of the three foundational concepts: WAter, LEan & GReen, and INdustry 4.0, resulting in WALEGRIN 4.0. The first cornerstone of the WALEGRIN 4.0 model incorporates exemplary water supply practices sourced from the expertise of successful water supply organizations, aiming to minimize water losses within their systems. Over the years of implementing practical water supply principles, the WLTF working group has identified a "missing link" contributing to the shortfall of anticipated results in many water supply organizations. They advocate for management changes, recognizing that reducing non-revenue water (NRW) transcends engineering issues to include elements of social sciences and management skills. This underscores the importance of integrating new disciplines into water supply organizations. Adapting behavior patterns and leveraging the latest knowledge and technologies are crucial in the ongoing effort to address water losses and improve the efficiency of water supply systems.

Simultaneously, as the WLTF working group explores ways to enhance public water supply efficiency, two emerging concepts in the global economy, Lean and Green management and Industry 4.0—are becoming essential for business success. Consequently, Industry 4.0 has been selected as the second cornerstone for the WALEGRIN 4.0 model, mainly regarding processes to reduce water losses. The integration of Industry 4.0 enriches opportunities beyond traditional good water supply practices.

The Lean and Green management concept is the third cornerstone of the WALEGRIN 4.0 model. By utilizing Lean principles and tools, the model seeks to create an ecosystem where all three cornerstones operate effectively, particularly in adopting new knowledge and technologies. Furthermore, it aims to identify, manage, and reduce all types of losses within water supply processes as guided by Lean and Green management principles.

By combining these three concepts into a cohesive model, WALEGRIN 4.0 addresses the shortcomings of models based solely on good practices, enhancing operations and the efficiency of water supply organizations. Recognizing the mutual support between Lean and Green management and Industry 4.0 is essential. The application of Industry 4.0 facilitates and improves the execution of Lean principles, thereby minimizing process losses. Conversely, Lean and Green management concepts ease the integration of new knowledge and technologies derived from Industry 4.0 into operations.

The second cornerstone of the model focuses on the digitalization of business by implementing the industry 4.0 concept. This aims to establish an intelligent water supply network that can be monitored and managed in real-time, leveraging new information and communications technology (ICT) innovations. To realize this vision, several challenges must be tackled:

The first challenge involves transforming the water supply system into a cohesive Cyber-Physical System (CPS).

The second challenge is adapting the organization to operate effectively in a data-rich environment.

The third challenge concerns the organization's readiness to utilize intelligent and predictive IT tools.

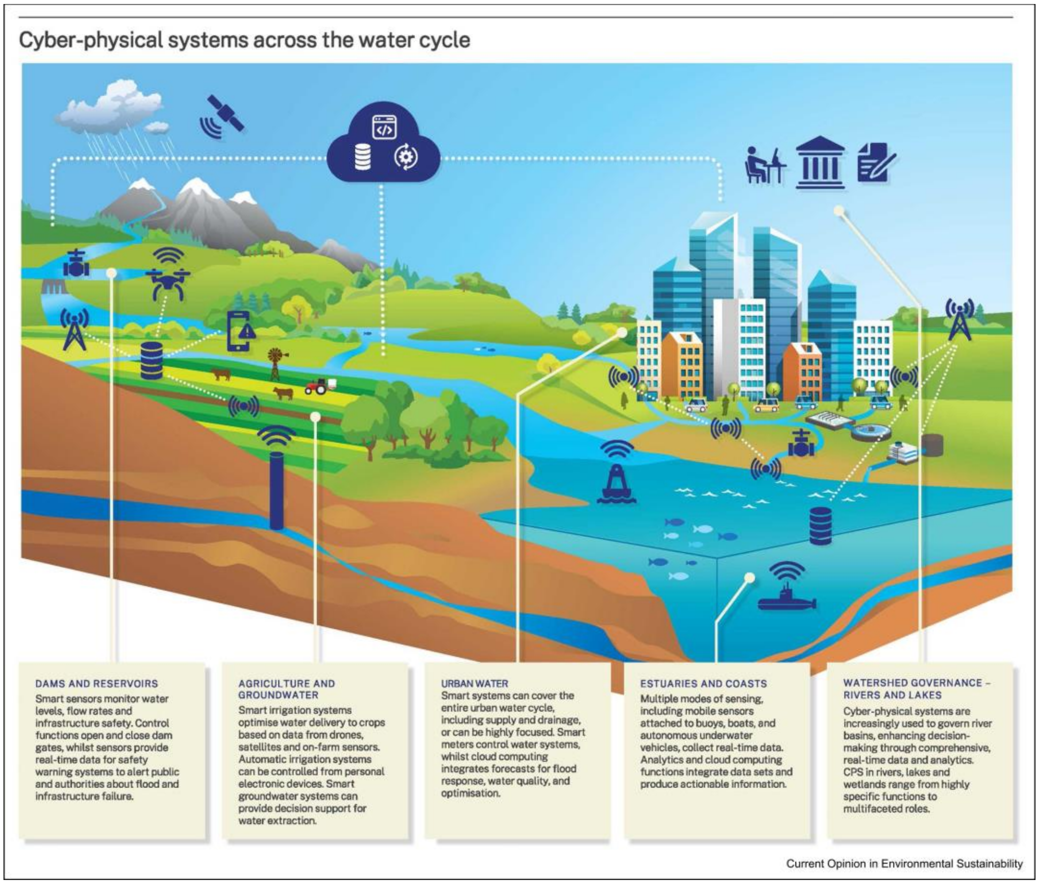
The development of the WALEGRIN 4.0 model employs knowledge and technologies from the industry 4.0 framework, detailed in the fourth chapter, to achieve the following objectives:

I. Establish an innovative CPS water supply network
II. Ensure collection, transmission, and storage of data (3P)
III. Support application deployment
IV. Conduct frequent measurements of water losses in District Metered Areas (DMAs)
V. Provide early detection of water losses
VI. Integrate a geographic information system
VII. Manage fleet operations effectively

The foundation for establishing an innovative Cyber-Physical System (CPS) water supply network is the current water supply infrastructure, which is enhanced by:

I. Installing SMART devices, such as sensors, meters, water flow monitors, actuators, and similar equipment.
II. Developing a strong, reliable, and accessible broadband telecommunications system for real-time data transmission.
III. Creating a data storage infrastructure, such as a data center.

Intelligent water supply networks can collect real-time data, transmit it, and store it for future use. By utilizing actuators, the smart CPS network can be proactively managed, allowing for system configuration, parameter adjustment, and the ability to turn sections of the water supply system on or off as needed.



Cyber-physical systems across the water cycle

DAMS AND RESERVOIRS
Smart sensors monitor water levels, flow rates and infrastructure safety. Control functions open and close dam gates, whilst sensors provide real-time data for safety warning systems to alert public and authorities about flood and infrastructure failure.

AGRICULTURE AND GROUNDWATER
Smart irrigation systems optimise water delivery to crops based on data from drones, satellites and on-farm sensors. Automatic irrigation systems can be controlled from personal electronic devices. Smart groundwater systems can provide decision support for water extraction.

URBAN WATER
Smart systems can cover the entire urban water cycle, including supply and drainage, or can be highly focused. Smart meters control water systems, whilst cloud computing integrates forecasts for flood response, water quality, and optimisation.

ESTUARIES AND COASTS
Multiple modes of sensing, including mobile sensors attached to buoys, boats, and autonomous underwater vehicles, collect real-time data. Analytics and cloud computing functions integrate data sets and produce actionable information.

WATERSHED GOVERNANCE – RIVERS AND LAKES
Cyber-physical systems are increasingly used to govern river basins, enhancing decision-making through comprehensive, real-time data and analytics. CPS in rivers, lakes and wetlands range from highly specific functions to multifaceted roles.

Current Opinion in Environmental Sustainability

Figure 5.1: A landscape-scale perspective of CPS applications in water management. CPS is embedded across the water cycle. Most CPS have a sensing layer (sensor nodes, drones, satellite images, etc.), a data transmission layer (i.e., WLAN, fiber networks, etc.), an application layer (cloud service, databases.), and an intelligent application layer for monitoring data, emergency response and evaluation [20]. Source: The original image concept was created by the authors for this paper, and scientific illustrator Cate Broadbent carried out the graphic design work.

Installing SMART devices—such as sensors, meters, water meters, actuators, and similar technologies—can be approached in two ways. The first approach involves prioritizing the installation across the entire water supply system. Since developing an innovative CPS water supply system is a multi-year endeavor, the number of installed smart devices will grow over time, enhancing system usability. This method is particularly effective for smaller water supply systems.

The same principle is applied for larger systems but within designated DMA zones. Priority is assigned to these zones based on various factors, including connection density, water consumption, water losses, economic significance, water quality, and other criteria relevant to the specific water supply organization.

However, installing smart devices does not establish a real-time data transmission system; this requires a robust, reliable, and cost-effective telecommunications infrastructure. Water supply organizations can utilize their existing buildings—such as water facilities and administrative buildings—to develop this infrastructure. In exceptional circumstances where significant challenges arise, they may use facilities owned by local government entities.

These organizations serve areas defined by the size and needs of the local community such that full coverage aligns the shape and size of the service area with the water supply network. This network includes water supply pipelines and other essential facilities, such as water storage tanks and pumping stations, strategically distributed throughout the system.

This existing infrastructure presents a significant advantage for water supply organizations, as there is no requirement to construct new facilities; current buildings can be easily outfitted with the devices and equipment needed to create a strong, reliable, and economical telecommunications infrastructure. Water supply organizations will also establish a data storage infrastructure (data center) based on a favorable techno-economic feasibility study. If the feasibility study yields negative results, the data center can be leased through an external partner (outsourcing).

5.2. Key performance indicators of water supply organizations

The established key performance indicators (KPIs) for water supply organizations and their monitoring are outlined in the Regulation on the Criteria for Economic Operations of Water Service Providers. Each organization must provide data on the efficiency of public water supply and drainage for the previous year to the Council for Water Services by June 1 of the current year. Upon analysis, it becomes evident that this data typically lacks the characteristics of KPI business indicators; instead, they serve as attribute indicators (AIs) that detail the water supply system's or organization's features. While attribute indicators effectively report on the size and characteristics of a water supply organization or system, they fall short in management applications for goal-setting purposes, unlike KPIs. For example, the number of properties connected to the public water supply system is an attribute indicator influenced by the service area's size. It does not reflect the achievements of the period. Effective goal management requires establishing adequate metrics that facilitate the comparison of current achievements to past accomplishments or plans.

The prescribed economic operation criteria fall into six categories. Water supply organizations vary based on service area characteristics (such as population density, terrain type, and soil composition), their size—measured by the number of connections—and the technology used, and the system's age. Thus, no two water supply organizations are identical. This leads to the proposal of new key performance indicators that can significantly aid water supply organizations in both internal and external comparative analysis and goal setting. Goal management necessitates using appropriate metrics to compare accomplishments with those of prior periods or future objectives. Monitoring intervals can range from daily to monthly, annually, or longer-term spans.

The specific economic operation criteria for water service providers include:

- Degree of Coverage by Water Services:
  - 1.1. Public water supply (%) = Number of properties connected to the public water supply system / Total number of properties.
  - 1.2. Public drainage (%) = Number of properties connected to the public drainage system / Total number of properties.
- Quantity of Water Services Provided:
  - 2.1. Quantity of produced (extracted) water in m^3 (daily, monthly, yearly) relative to the total population.
  - 2.2. Quantity of delivered water in m^3 relative to total population and number of connections (by consumer categories).
  - 2.3. Quantity of treated wastewater (both treated and untreated) in m^3 over set periods relative to total population and number of connections.
- Quantity of Billed Public Water Supply Services:
  - 3.1. Unbilled public water supply service (%) = (Total delivered quantity of water – Quantity of billed public water supply service) / Total delivered quantity of water.
  - 3.2. Water losses (m^3 of unbilled water/km of network/day and number of connections).
- Quality of Water Services:
  - 4.1. Breaks/bursts per km of network (separate for breaks and bursts).
  - 4.2. Hours of interruption in public water supply service / Total hours of public water supply service during the year.
  - 4.3. Number of non-compliant water/wastewater samples relative to total samples.
  - 4.4. The same indicator is from an independent laboratory.
  - 4.5. Number of resolved complaints regarding water service quality within 15 days (or complaints relative to number of connections/number of received complaints).
- Costs:
  - 5.1. Costs of public water supply and drainage services / total operating costs:
    - a) Water supply costs / total operating costs / total delivered quantity of water.
    - b) Water supply costs / total operating costs / total extracted quantity of water.
    - c) Drainage costs / total operating costs / total quantity of treated wastewater.
  - 5.2. Costs of public drainage services / Number of inhabitants connected to public drainage.
  - 5.3. Total number of workers relative to number of connections (public water supply + drainage).

    - 5.4. Total employee costs / Number of connections (public water supply + drainage).
    - 5.5. Number of public water supply workers / Total number of workers.
    - 5.6. Number of public drainage workers / Total number of workers.
    - 5.7. a) Total labor costs / Total operating costs; b) Electricity costs / Total operating costs; c) Maintenance costs / Total operating costs; d) Depreciation costs / Total operating costs; e) Other material costs / Total operating costs.
    - 5.8. Degree of coverage of water service costs (Revenue from regular operations / Total costs of regular operations).
- Indebtedness and Capital:
    - 6.1. Degree of indebtedness.
    - 6.2. Company capital / Number of inhabitants in the service area.

"Energy losses constitute the most significant financial burden for water supply organizations, stemming directly from water losses and the energy potential of each cubic meter of lost water. Consequently, these organizations implement various measures to enhance the energy efficiency of their pumping stations, such as installing soft start devices for pumps, continuous pump regulation, and optimizing pump operations. Over 80% of a water supply organization’s electricity consumption occurs at these pumping stations. As previously mentioned, energy losses are linked to water losses due to the potential energy imparted to the water at these facilities. Each cubic meter of water in the supply system carries a specific amount of energy dictated by the system's parameters. Therefore, it follows that minimizing water losses in the supply network will also directly decrease electricity consumption, as indicated by the key performance indicator (KPI) for electricity consumption per water intake (Q) [Kwh/m^3]. Additionally, further reductions in energy costs can be achieved by generating electricity from renewable sources. By fully embracing energy efficiency, overall electricity costs in the water supply system can be eliminated. The energy loss efficiency of the public water supply system is monitored using designated key performance indicators (KPIs). To further enhance the management of energy losses, the following additional KPIs are recommended:

- Electricity consumption per revenue water (QRW) [Kwh/m^3]
- Electricity consumption per intake water (Q) [Kwh/m^3]
- Electricity consumption per 1000 connections [Kwh/1000 WSC]
- Electricity consumption per kilometer of water supply network [Kwh/km WSN]
- Share of electricity from renewable sources in total electricity consumed [%].”

5.2.1. Guidelines for Better Utilization of Employee Potential

Insufficient utilization of employee potential is a challenge in water supply organizations. Optimizing employee potential is crucial for developing the comprehensive model WALEGRIN 4.0. By employing Lean and Green management principles and tools, we can enhance the effective use of employee potential, as these tools are fundamentally based on leveraging employee capabilities. For example, Lean management, which focuses on continuous improvement and includes all employees, from frontline workers to management—is crucial. Employee participation in digital transformation and the implementation of early loss detection methods for water and other ongoing improvement initiatives will be evaluated by the number of proposals made and successfully implemented. The efficiency of the public water supply system in relation to employee potential utilization will be tracked using specified key performance indicators (KPIs). Additionally, the following KPIs are proposed for enhancing employee potential utilization:

- Number of water supply employees per 1,000 connections [1/1000WSC]
- Number of water supply employees per kilometer of the water supply network [1/kmWSN]
- Ratio of direct employees to the total number of water supply employees [%]

5.2.2. Guidelines for Reducing Water Losses

The importance of water losses from supply systems is primarily influenced by the effectiveness of early detection methods for identifying these losses in an accurate model of a bright District Metered Area (DMA). Testing on an actual intelligent DMA model has demonstrated that implementing the WALEGRIN 4.0 model allows for real-time monitoring of water losses, significantly reducing such losses from the water supply system. The efficiency of the public water supply system concerning water losses (QNRW) is tracked using established key performance indicators (KPI). To enhance water loss management, the following additional key performance indicators are recommended: - QNRW / KMWSN: Actual water loss per kilometer of the network [m3/kmWSN]; - QNRW / 1000WSC: Actual water loss per 1,000 connections [m3/1000WSC];

5.2.3. Guidelines for Better Inventory Management

The challenge of excessive inventory represents a common and significant loss for water supply organizations, which can be addressed from various angles. Utilizing lean management principles and tools will enable us to effectively decrease the quantity and value of inventory necessary to operate public water supply systems. We will eliminate unnecessary inventory by implementing the Just-In-Time (JIT) business principle and employing Total Productive Maintenance (TPM) alongside standardized work practices. Inventory management efficiency within the public water supply system is assessed using the key performance indicators (KPIs) outlined previously. Additionally, the following KPIs are recommended for improved inventory management:

- Inventory value per 1,000 connections [€/1,000 WSC]
- Inventory value per kilometer of the water supply network [€/km WSN]
- Inventory value as a percentage of total water supply revenue [%]
- Current inventory value compared to the previous period's inventory value [%]

5.2.4. Guidelines for Improving CRM Processes

Implementing the integral model WALEGRIN 4.0 will introduce a Customer Relationship Management (CRM) system, enabling us to effectively manage customer relationships throughout the contracting, sales, billing, and complaints processes. By utilizing SMART water meters in the billing process for utility water consumption, we will ensure that consumers receive invoices based solely on actual, accurate meter readings. This improvement is expected to significantly reduce the number of complaints from inaccurate consumption assessments, which currently represent the largest share of total complaints. As a result, there will be a reduction in the indirect staff required in the customer relations department and a decrease in the accounting staff needed to handle individual invoice corrections related to approved complaints. Consequently, all associated indirect costs will also diminish. Additionally, SMART water meters assist the CRM system by informing users about and managing their consumption. A notable advanced feature of these meters is their ability to detect water losses on the consumer side. Reducing such losses will decrease the write-off of unused water, which is a component of the overall losses in the water supply system. The effectiveness of the public water supply system in fostering better relationships with users through the CRM will be monitored using established and proposed key performance indicators (KPIs): the number of complaints per 1,000 connections [1/1000 WSC], the number of complaints per kilometer of the water supply network [1/km WSN], and the comparison of the number of complaints in the current period against those in the previous period [%].

5.2.5. Organizational structure and development of supporting processes VIO

According to the new General and Technical Terms of Delivery for Water Services, the Supplier is exclusively authorized and responsible for installing water meters connected to the AMWR network. The Supplier or its authorized partners must carry out installation work. After installation, all water meters are sealed and undergo quality control in compliance with the Supplier's regulations, with relevant data entered into the Supplier's information system (GIS and billing UPN VIO). The Supplier is responsible for maintaining the accuracy and functionality of the water meters; users are required to facilitate this process.

The Supplier will manage the installation, replacement, and maintenance of water meters, either directly or through collaborators. Water meters and the accompanying telecommunications equipment, which connects to the water meter for integration into the AWMR network, are the Supplier's core assets and remain its property. Users are only responsible for water meter procurement and installation costs at the initial contracting phase.

Typically, the Supplier will install and connect central water meters (GV) to the AWMR network at its own expense, following its planned schedule based on the expansion of access points and the routine replacement and maintenance plan for water meters, which users must support. However, suppose a user requests a connection to the AWMR network, necessitating the installation of a GV and related equipment before the scheduled replacement. In that case, the user will be required to cover the costs of the GV installation.

Telecommunications equipment integral to the AWMR network, which facilitates the connection of water meters to the remote network, is installed and maintained by the Supplier at its own expense, with users expected to assist in this task. This equipment is a fundamental asset of the Supplier and includes the data generated, which is recorded in the Supplier's information system (GIS and billing UPN VIO).

The Supplier monitors and oversees the AWMR network and water meters from its monitoring-control center (NKC-AWMR). Users can report network malfunctions or issues regarding water meter readings to NKC-AWMR via phone, email, the Supplier's official website, or the MOJ VIO portal.

5.3. Organization of the Information and Telecommunications Process

A new Department for the Construction and Maintenance of the AWMR network (Department for AWMR) will be established within the existing IST Service to implement the required regulations. This newly created department will collaborate closely with all components of the IST Service and with other divisions within VIO, particularly the Sales Service, the Water Meter Change Department, and the Technical Preparation Department.

In addition to internal collaboration within VIO, the AWMR Department will maintain close cooperation and serve as the primary point of contact for external partners responsible for installing, maintaining, and replacing water meters in buildings as part of the AWMR network's construction and upkeep. They will also engage with partners involved in installing, maintaining, and upgrading telecom equipment as required.

The structure of the IST Service will change, and new responsibilities related to AWMR and the new billing system will be assigned to existing departments. The IT Department will need to embrace the following new responsibilities and adapt its work processes accordingly:

- Provide program support for receiving readings from MARS and handle all system maintenance programming tasks by reading dynamics and invoice generation.
- Offer program support for developing and maintaining payment UPN and e-UPN across databases.
- Provide program support for the development and upkeep of the MOJ VIO Internet portal, aligning with operational needs, noting that Global Design-GD will handle most maintenance.
- Support the ongoing maintenance and enhancement of the Mixed Water Billing System for buildings.

Similarly, the IT and Telecommunications Department (located at Folnegovićeva) will need to take on the following new tasks and adjust their work processes accordingly:

- Support in constructing and maintaining telecom equipment for the AWMR network as required by the AWMR Department.
- Ensure the necessary support for maintaining access points (APs).
- Handle tasks related to procuring telecommunications connections, such as ADSL connections.

The newly established AWMR department will be responsible for the following tasks:

- Conduct field visits based on requests from the Procurement Department and establish specific technical requirements for connecting to the AWMR network.
- Preparing cost estimates for AWMR about existing buildings and water connections where water meters are already in place (such as M-BUS-SV for family homes, GV for old internal systems, and GV for industrial setups).
- Engaging customers for technical clarifications regarding the installation of AWMR connections.
- Executing AWMR connections by work orders initiated by the Sales Department, following the signing of contracts for installing water meters and connections to the AWMR network.
- Regarding the installation of AWMR connections, the department will be responsible for:

    - Coordinating the installation of TK equipment with external contractors, ensuring quality control of the installed equipment, and entering installation data into the UPN system.
    - Coordinating the installation of water meters (IV and SV) with external contractors, ensuring quality control, and entering installation data into the UPN system.
    - Coordinating the installation of access points (AP) with external contractors, ensuring quality control, and entering installation data into the UPN system.
- Closing work orders after tasks are completed and generating reports.
- Issuing work orders for water meter replacements to the department responsible for replacing GV with new water meters (UZV) connected to the AWMR network according to its construction plan for existing VIO connections.
- Planning the AWMR network.

5.3.1. Organization of Support Processes

As part of the supporting processes that significantly contribute to the construction and maintenance of the AWMR network, the following departments are involved:

- Sales Department
- Procurement Department
- Water Meter Replacement Department
- Technical Preparation Department

The Sales Department plays a vital role in the AWMR supporting process and is tasked with:

- Receiving requests for AWMR connections
- Directing the AWMR department to the field to identify specific technical conditions for connecting to the AWMR network, which includes determining the technical requirements for executing the connection based on the received request
- Issuing orders to the AWMR department for the connection of existing services to AWMR
- Instructing the Technical Preparation Department to proceed with the development of new connections
- Finalizing contracts based on accepted cost estimates (specifically for the installation of water meters and connection to the AWMR network)
- Initiating work orders for installing AWMR connections from the UPN based on the signed contract and payment.

The Water Meter Replacement Department is also involved in the AWMR supporting process and is responsible for:

- Replacing existing gate valves (GV) in line with the construction plan of the AWMR network and the work order issued by the AWMR Department, which entails replacing the existing GV with a new water meter of suitable specifications
- Preparing cost estimates for GV installation when the customer is responsible for the installation costs
- Contributing to the development of the construction plan for the AWMR network regarding the regular replacement of GV according to a set timeframe
- Executing the replacement of GV and service valves (SV) according to a specified timeframe.

The Procurement Department is an integral part of the AWMR supporting process and is responsible for:

Preparation of tender documentation for the public procurement of equipment for the AWMR network, including water meters and TK equipment for the remote reading system. This involves the publication of public tenders related to the items above, the procurement of equipment, and the storage of procured items in the warehouse. Monitoring the status and quantity of equipment in storage and establishing a min-max system to signal the quantities of equipment in stock is essential. The warehouse is responsible for issuing equipment according to the quantities specified in the work order from UPN, which is upgraded in line with the project requirements.

The Technical Preparation Department is involved in supporting the AWMR process and is responsible for:

- Receiving requests from the Sales Department for new connections and new buildings.
- Preparing cost estimates, in collaboration with the AWMR Department, for constructing the AWMR network at new connections and buildings.
- Coordinating with the AWMR Department regarding installing equipment associated with constructing the AWMR network at the new connections.
- Collaborating with the AWMR Department in developing the AWMR network construction plan.

The installation of the AWMR connection involves telecommunications equipment (TK) and water meters, which include:

- Main water meter (all customer categories)
- Secondary water meter (for new constructions)
- Internal water meter (for older buildings)
- Recorder (applicable to all customer categories, only when connected to pulse water meters)

- Signal repeater (applicable to all customer categories)
- Concentrator (applicable to all customer categories)

Given the variety of equipment, it is essential to maintain a record of the types and monitor them by type and serial number (ID). This equipment must be documented by type and code in the warehouse management system and accessible for integration into the UPN database.

It is also crucial to consider scenarios where water meters with integrated radio modules are installed in the local AWMR network. In this case, recorders will not be installed, and their corresponding data (ID/channel) will not be required; instead, only the water meter data (including the factory number or other identifiers recognized by the MARS system) must be reported.

Shortly, VIO will primarily focus on procuring new UZV water meters equipped with integrated radio modules, specifically Wireless M-BUS, for all relevant cases.

To install AWMR equipment, it is essential to generate relevant work orders to facilitate the installation of AWMR TK equipment and water meters in the field. A work order (WO) serves as a document that initiates equipment issuance from the warehouse, activates field personnel (installers) for on-site work, and records data related to the installed AWMR equipment. Consequently, the WO must be linked to the warehouse for retrieving material data (codes and names of materials/parts), to POSIS for personnel information (codes, names, surnames), and to UPN and GIS for providing data on the installed equipment and its spatial pairing. Additionally, the WO requests material issuance from the warehouse. Activation of the WO occurs after a contract has been executed and signed (3.1) and a contract number has been established, facilitating the WO's activation. The WO must also include an open customer code and measuring point codes. Work orders must also be enabled for scenarios where a contract is not mandatory, such as connections made for subsidiaries within Zagreb Holding. The WO can only be activated after a connection contract (and associated payments are completed), provided the customer code and measuring point codes are opened post-contract signing. For all equipment installations, connecting the AWMR system for reading water meters and the billing system relies on linking the registrant's code (or the water meter itself with a radio module) to the customer code. Installers should input this data in the field using mobile devices following equipment installation. To establish a work order system via mobile devices, a specific project task (Infosistem) needs to be created. A complete history of water meter installations and AWMR TK equipment replacements must be maintained in UPN. The WO must be linked to the GIS system VIO, enabling the installer, who has installed the equipment in the field, to access the connection location data (spatial data – coordinates) through a mobile device, along with pairing all field data with that information and transmitting it to UPN/GIS via mobile device.

5.4. Water Loss Reduction and Financial Savings Plan

The primary advantage of the AWMR network is anticipated to be the decrease in losses within the water supply system. The remote reading of water meters and the billing system form a crucial part of the technical framework designed to minimize water losses. Central to this technical model is the GIS, which is required to provide input data for the hydraulic model (HM) to determine the appropriate pipeline specifications (including pipeline characteristics, pressures, flow rates, and consumption in individual DMA zones). Water consumption constitutes critical information that the GIS must acquire from the UPN (billing system), which will derive this data from the AWMR network. This integration sequence has the potential to enhance the loss reduction system significantly, provided that the AWMR network is fully established with the creation of DMA zones and that consumption data can be accessed at least daily. In 2013, water losses in the City of Zagreb were approximately 50%, representing non-revenue water (NRW), with actual losses (WL) amounting to around 45% of the extracted water. By implementing a technical model as illustrated in Figure 12-5, it is possible to address water losses and reduce them to the threshold of unavoidable losses, which is contingent upon various technical parameters of the system, such as the length of the water supply pipeline, the number of connection points, the distance from the property boundary to the water meter, and the system pressure. The objective is to reduce losses (NRW) to below 30% by 2020. The AWMR, as a crucial element of the technical system for loss reduction, not only impacts actual losses—which can be decreased through the appropriate hydraulic model (HM)but also plays a vital role in reducing apparent losses by enhancing the accuracy of the water meters that will be installed shortly.

5.5. How to start a project

Initiating and completing a project is a complex endeavor. It involves managing resources, handling risks, and coordinating with municipal administration and project participants. Key project elements include human resources, materials, equipment, projected timeline, and available funds. The typical project phases encompass initiation, planning, implementation, monitoring and control, completion, effects monitoring, and result evaluation.

Thorough planning is crucial for ultimate success, necessitating a precise definition of all implementation steps and activities. The primary objective during this phase is to plan timing, costs, and resources and mitigate implementation risks. Errors and omissions during planning can significantly hinder project success. Mitigating such risks involves establishing a planning team, defining achievable goals and enabling activities, assessing financial resources, estimating time and costs, creating activity schedules, preparing project budgets, planning for implementation risks, involving citizens in planning and implementation, and obtaining necessary permits.

Comprehensive and well-prepared project documentation is essential. It encompasses all necessary paperwork to design, develop, and describe the project and obtain required permits. Quality documentation is vital for securing project financing from various sources, including domestic and European funds and commercial banks. Deficient or poorly prepared documentation can lead to project implementation issues despite the project's merit.

5.6. Project risk management

Organizations often embark on projects to fulfill strategic objectives, such as implementing a revised strategy or enhancing operational processes. The selection of projects and programs defines an organization's tactical approach to strategy implementation. It is essential to differentiate between project risk management, focused on delivering projects on time, within budget, and meeting quality standards, and the project's overall purpose.

Additionally, project risk management must consider the risks inherent in the project, including the appropriate allocation of funds and whether the project will deliver its full benefits. An example is evaluating the decision to host the 2012 London Olympics and whether it aligns with the broader strategic plans for the city and the UK economy.

Project risk management extends conventional project planning to minimize outcome variability and control risks. It involves identifying and responding to uncertain events to maximize opportunities and minimize adverse impacts. This approach ensures flexibility in managing risks and capitalizing on favorable project developments.

Furthermore, project risk management aligns with control management and is especially relevant to projects involving construction, new products, IT systems, technology, or market expansion. Projects are often considered risk-reduction endeavors to achieve specific management objectives and gain a competitive advantage.

Project risk management focuses on delivering projects within defined cost, time, and quality parameters. It encompasses forward-looking measures to anticipate and address potential problems. It includes managing compliance hazards, controlling risks, and seizing opportunities to enhance project delivery.

To manage uncertainty in projects, organizations can choose from various courses of action, from accepting and adapting to risks to adopting contingency plans or avoiding certain uncertainties altogether. Risk matrices aid in visualizing potential risks and their impact on project timelines and costs, enabling project managers to make informed decisions.

In summary, project risk management involves minimizing uncertainty, introducing controls, and seizing opportunities, all essential for successful project delivery in line with organizational objectives.

5.6.1. Project risk register

Throughout the project, it is essential to populate and update a risk register or risk matrix regularly. A risk management software tool can be cost-effective in maintaining the register, reducing manual workload, and prioritizing risk management activities. After identifying risks and implementing mitigation plans, it is crucial to regularly review them, as the project environment is constantly changing. Some risks may diminish while unforeseen ones may emerge, underscoring the need for continuous updates to the risk register and the generation of regular reports. These management reports should offer clear visibility of the risks, help prioritize activities, and facilitate decision-making.## Project Lifecycle and Risk Management

Project risk management has evolved into one of the most well-developed and respected risk management branches. This is no surprise considering the dynamic and high-pressure environments in which many projects operate. Whether implementing a new software package, constructing a major sports stadium, or delivering a large-scale event like the Olympic Games, projects of varying scales go through distinct stages. Figure 31.3 outlines the critical stages in the project lifecycle.

A crucial aspect of project risk assessment is that the client's requirements should always take precedence. Although the client may be external to the organization, they might also be an internal part. The project lifecycle is categorized into four stages: project initiation, project planning, project execution, and project closure, as detailed in Figure 31.3.

A risk register or matrix should be regularly updated throughout the project, with risk management software tools often proving cost-effective. Once risks have been identified and plans to mitigate them are in place, it is crucial to review them regularly due to the constantly changing internal and external project environment. The risk register needs to be continuously updated, and reports should be generated regularly to provide clear visibility on the risks faced and facilitate decision-making.

Each stage of the project lifecycle inherently carries significant risk and uncertainty. These uncertainties manifest as issues such as project definition, budget and schedule agreements, and performance/specification confirmation. The level of uncertainty decreases as the project progresses, but it is vital to note that making changes becomes increasingly costly as the project advances.

Good project planning should include provisions for unforeseen events or circumstances, often called contingency. Identifying difficulties and exploring opportunities to overcome them become essential as projects develop. Additionally, a well-managed project should utilize specification changes to enhance customer satisfaction and organizational income.

The Association for Project Management (APM) has developed the Project Risk Analysis and Management (PRAM) Guide, which provides activities that can be initiated at various stages of a project. The PRAM model identifies five key project stages where significant benefits can be derived from its application. These include feasibility, sanction, tendering, post-tender, and implementation.

Project risk analysis and management enhance the likelihood of a project's successful completion within budget, time, and performance parameters. Although statistical assessment of risks with ample data is feasible, the unique nature of each project often necessitates a systematic risk management process. It is critical to integrate risk management seamlessly into project management and not treat it as an optional or sporadic endeavor.

In conclusion, effective risk management should be integral to the overall project management process. Project decisions should be made with a keen awareness of the associated risks. Risk management must also be well-integrated with other project management processes, fostering a seamless interface across boundaries.

5.6.2. Internal audit activities

There should be a close collaboration between risk management and internal audit, with each function holding varying responsibilities that depend on the organization's nature, type, and size. This partnership is crucial as successful risk management hinges on four essential risk-based outputs, commonly known as MADE2:

I. Mandatory requirements as stipulated by laws, customers/clients, and standards
II. Assurance for management and stakeholders
III. Decision-making based on the best available information
IV. Effective and efficient core processes organization-wide

All stakeholders must work together to achieve these outputs, including risk management and internal audit. Chapter 34 explores the activities relating to risk assurance, while subsequent chapters detail the extensive contributions and undertakings of the internal audit department.

Given that internal control ensures that a business meets its objectives, there is a clear connection with risk management. The internal audit department typically evaluates internal control activities within large organizations. While there are distinctions between internal audit and risk management approaches and activities, common interests exist, and effective collaboration is essential.

Internal audits primarily focus on risk assurance and are performed by the non-executive audit committee in large organizations. In contrast, risk management is an executive function undertaken by the organization's executive members. Moreover, the risk management committee should ideally be chaired by an executive board-level director.

A robust internal control system reduces the likelihood of poor decision-making, human error, control circumvention, management overrides, and unforeseen circumstances. However, it cannot entirely eradicate these risks. Therefore, it provides reasonable, but not absolute, assurance that a company can achieve its objectives and conduct its business orderly and legitimately.

5.6.3. Expectations of Internal Control

Internal financial controls form part of a charity's overall control framework and extend beyond financial matters to encompass all the organization's systems and activities. Executive management, staff, and volunteers must uphold the controls established by the trustees. Notably, a prevalent culture of control should be embedded in the organization's operations, led by the trustees and senior management.

The trustees must conduct an annual review of the effectiveness of the internal financial controls, ensuring they are appropriate for the charity's context and not overly burdensome. Moreover, a critical aspect of internal financial controls ensures that no single individual has sole responsibility for any transaction from authorization to completion and review.

5.6.4. Role of Internal Audit

Figure 35.1 provides an overview of the activities required for a successful Enterprise Risk Management (ERM) initiative, delineating the core roles of internal audits within the internal audit department. These encompass reviewing key risk management, assessing risk reporting, and evaluating risk management processes. However, settings such as risk appetite and decisions on risk responses should not involve internal audit; instead, internal audit's involvement in certain activities requires proper safeguards.

The three lines of defense model, aligned with internal audit's role in ERM, emphasizes management's primary responsibility for risk management, alongside specialist risk management functions' support and internal audit's validation of the risk management process and framework.

Establishing audit priorities is crucial for internal auditors about risk management activities, as they need to ascertain the testing of controls. A significant interface exists between risk management and internal control, with risk management professional's adept at evaluating risks and identifying suitable control measures, which are subsequently evaluated by internal audit.

5.6.5. Undertaking an Internal Audit

An internal audit exercise involves several steps, from planning and fieldwork to producing the audit report and ensuring adequate follow-up. Integral to this process is collecting relevant information and subsequent analysis to determine the review's priorities and objectives. The fieldwork phase encompasses testing controls, visits to various locations, and evaluating associated risks.

The audit report will reflect the efficiency and effectiveness of the controls and any recommendations for further enhancement. Notably, internal auditors must form an independent opinion regarding the achieved level of control and ensure that agreed recommendations are implemented.

5.6.6. Allocation of Responsibilities

The delineation of responsibilities between internal audit, risk management, and line management can vary among organizations. A clear understanding of these roles is crucial for risk ownership. While risk management aids risk assessment activities and control design, internal audit is supported by auditing the controls' effectiveness and implementation. Both ultimately maintain that management retains primary responsibility for risk management.

This approach ensures that risk management and internal audit endeavors enhance, rather than undermine, the organization's risk management. It aligns with the core tenet of most risk management standards, indicating that risks should be managed within their originating contexts.

The working relationship between risk management and internal audit presents advantages and disadvantages. While a harmonized approach may prove beneficial, a clear distinction in responsibilities is vital to avoid diminishing management's risk ownership and safeguard the internal audit's independence. The text has been extensively revised to enhance clarity and structure while faithfully representing the original content. The tone is maintained at a standard level to maintain a professional and informative style.

5.6.7. Five lines of assurance

There has been substantial discussion about the function of the three lines of defense model. For instance, an organization that has embraced this approach must consider where head office functions fit within the three lines, as they will often carry out first- and second-line activities and, possibly, operate as third line. Specifically, the treasury function within the head office of a large company will oversee the organization's treasury requirements as first-line managers. Additionally, the treasury function will provide expertise in deciding the strategy and tactics to be adopted by the organization. Sometimes, the treasury function audit is outside the scope of an internal audit department in a large company. It will, therefore, be the external auditors that review and audit the treasury function.

Another weakness of the three-line defense model is that it is more relevant to hazard (or operational) risks, including internal financial control. The three-line defense model is also well suited to governance compliance risks. However, the audit committee generally does not audit the upside of risk or seek to identify circumstances where opportunities have been missed.

Another aspect of the three lines of defense model relates to the role and status of the board of directors. The board provides assurance but is not usually identified as a line of defense. Instead, the board acts as a stakeholder group, receiving assurance from various departments within and outside the organization, including external auditors. The board then uses this assurance to assure other stakeholders, including external ones.

The board will receive assurance from departments inside and outside the organization, including external auditors. The three lines of defense model is well established, but sometimes, it is extended to five lines of defense by showing external audit as the fourth line and regulators as the fifth line. However, this does not represent the five lines of assurance approach, as it is currently being developed. An alternative approach to the five lines of assurance has been put forward to enhance the effectiveness of the three (or five) lines of defense model.

The five lines of the assurance model suggest the following sources of assurance:

The board of directors ensures that effective risk management processes are in place and that the other lines manage risk within the appetite.

Senior executives and managers are responsible for building and maintaining a robust risk management process and delivering reliable information on the principal risks.

Business unit leaders with assigned ownership or responsibility for reporting specific risks and ensuring resources are protected and objectives are achieved.

Specialist units provide expertise on specific types of risk, such as treasury, safety, environment, legal, and insurance, and are responsible for related risk management processes. Internal audit activities, providing independent and timely information to the board on the reliability of the risk management processes in the organization and producing consolidated reports. Inevitably, there will be variations in the format described above, and different organizations will develop a structure for the five lines of assurance that suit their specific needs. The primary enhancement to the three lines of defense model, as provided by the five lines of assurance model, is that the first line of defense is divided into the board, senior executives, and business unit leaders, each of these identified groups being responsible for assuring relation to their allocated responsibilities. One of the benefits of the five lines of assurance model is that improved communication is required between the board of directors, members of the executive, and the business unit leaders. Also, close liaison is required between the specialist expert risk units and the internal audit activities. The focus is on providing consolidated assurance across the organization to enhance a risk-aware culture rather than concentrating on the design and implementation of controls. Therefore, the five lines of assurance model is more relevant to managing strategic and tactical risks (including opportunities) than the three lines of defense model. This fact arises directly from the increased focus on assurance in the five lines of assurance model rather than control in the three lines of defense model. It should be noted that, in both models, external auditors and regulators will continue to fulfill their specific responsibilities.

Chapter VI:
SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

6.1. Summary

Management should establish and operate monitoring activities to monitor the internal control system and evaluate the results. Attributes The following attributes contribute to the design, implementation, and operating effectiveness of this principle:

- Establishment of a Baseline
- Internal Control System Monitoring
- Evaluation of Results

Management establishes a baseline to monitor the internal control system. The baseline is the current state of the internal control system compared to management's internal control system design. The baseline represents the difference between the criteria of the design of the internal control system and the condition of the internal control system at a specific point in time. In other words, the baseline consists of issues and deficiencies identified in an entity's internal control system. Once established, management can use the baseline as a criterion in evaluating the internal control system and make changes to reduce the difference between the criteria and condition. Management reduces this difference in one of two ways. Management either changes the design of the internal control system better to address the objectives and risks of the entity or improves the operating effectiveness of the internal control system. As part of monitoring, management determines when to revise the baseline to reflect changes in the internal control system. Management monitors the internal control system through ongoing monitoring and separate evaluations. Ongoing monitoring is built into the entity's operations, performed continually, and responsive to change. Separate evaluations are used periodically and may provide feedback on the effectiveness of ongoing monitoring. Management performs ongoing monitoring of the design and operating effectiveness of the internal control system as part of the ordinary course of operations. Ongoing monitoring includes regular management and supervisory activities, comparisons, reconciliations, and other routine actions. Ongoing monitoring may consist of automated tools, which can increase objectivity and efficiency by electronically compiling evaluations of controls and transactions. Management uses separate evaluations to monitor the design and operating effectiveness of the internal control system at a specific time or of a particular function or process. The scope and frequency of separate evaluations depend primarily on assessing risks, the effectiveness of ongoing monitoring, and the rate of change within the entity and its environment. Separate evaluations may take the form of self-assessments, which include cross-operating unit or cross-functional evaluations. Separate evaluations include audits and other evaluations that may involve reviewing control design and direct internal control testing. These audits and other evaluations may be mandated by law and are performed by internal auditors, external auditors, the inspector general, and other external reviewers. Separate evaluations provide greater objectivity when performed by reviewers who are not responsible for evaluating activities. Management retains responsibility for monitoring the effectiveness of internal control over the assigned processes performed by service organizations. Management uses ongoing monitoring, separate evaluations, or a combination of the two to obtain reasonable assurance of the operating effectiveness of the service organization's internal controls over the assigned process.41 Monitoring activities related to service organizations may include the use of work performed by external parties, such as service auditors, and reviewed by management.

Management evaluates and documents the results of ongoing monitoring and separate evaluations to identify internal control issues. Management uses this evaluation to determine the effectiveness of the internal control system. Differences between the results of monitoring activities and the previously established baseline may indicate internal control issues, including undocumented changes in the internal control system or potential internal control deficiencies. Management identifies changes in the internal control system that either have occurred or are needed because of changes in the entity and its environment. External parties can also help management identify issues in the internal control system. For example, complaints from the general public and regulator comments may indicate areas in the internal control system that need improvement. Management considers whether current controls address the identified issues and modifies controls if necessary. Management evaluates and documents internal control issues and determines appropriate corrective actions for internal control deficiencies on a timely basis. Management evaluates problems identified through monitoring activities or reported by personnel to determine whether any issues rise to the level of an internal control deficiency. Internal control deficiencies require further evaluation and remediation by management. An internal control deficiency can be in the internal control's design, implementation, or operating effectiveness and related processes.44 Management determines from the type of internal control deficiency the appropriate corrective actions to remediate the internal control deficiency on a timely basis. Management assigns responsibility and delegates authority to remediate the internal control deficiency. Management completes and documents corrective actions to remediate internal control deficiencies on time. These corrective actions include the resolution of audit findings. Depending on the nature of the deficiency, either the oversight body or management oversees the prompt remediation of deficiencies by communicating the corrective actions to the appropriate level of the organizational structure and delegating authority for completing corrective actions to appropriate personnel. The audit resolution process begins when audit or other review results are reported to management and is completed only after action has been taken that (1) corrects identified deficiencies, (2) produces improvements, or (3) demonstrates that the findings and recommendations do not warrant management action. With oversight from the oversight body, management monitors the status of remediation efforts so that they are completed on time.

Water supply systems worldwide grapple with actual and relative water losses, universally acknowledged as critical performance indicators (KPIs) for water supply organizations. To address this, organizations must assess their technical efficiency to achieve greater sustainability. This paper introduces the WALEGRIN 4.0 model, developed based on principles of adequate water supply practices, Lean and Green management, and the industry 4.0 framework. The model is designed to enhance the operational efficiency of water supply organizations for both technical and economic recovery.

The WALEGRIN 4.0 model emphasizes a strategic approach to actively managing water losses through system zoning and implementing District Metered Areas (DMA). This strategic approach, combined with incorporating Lean and Green management principles, advocates using proven tools and methods to eliminate organizational and technical losses. It also helps organizations adapt to new knowledge and technologies. The industry 4.0 concept further integrates innovative technologies to create an intelligent Cyber-Physical System (CPS) for water supply, instilling confidence in the model's effectiveness.

The WALEGRIN 4.0 model proposes a novel early indication method for detecting water losses, known as RIGV, which utilizes advanced SMART water meters. These meters serve dual purposes: measuring water consumption and managing water loss. Their ability to monitor water usage over shorter intervals facilitates timely loss management. The model for an intelligent DMA zone, developed and tested to validate the effectiveness of the RIGV method, revealed that real-time water consumption measurements are achievable, with data transmitted and recorded in a database almost instantly. This reliance on advanced technology should reassure you of the model's effectiveness.

By analyzing consumption data over defined periods, the model can calculate actual and relative water losses—essential KPIs—specific to the DMA zone. Combined with graphical representations of losses, this analysis distinguishes between water losses attributed to consumer behavior and those arising from the water supply system's condition. Control charts were created to monitor water losses, establishing stability limits and critical thresholds.

With the gathered data on actual and relative water losses, DMA zones can be prioritized for predictive maintenance of the water supply system. Subsequent data processing filtered out consumer-related losses, revealing a clear trend in actual water losses within the DMA zone. A stable trend near the control limits indicates steady operations, while an upward trend signifies losses due to new failures. In all three scenarios tested, where water losses increased, the method effectively detected rising trends shortly after simulated failures.

This early indication method, RIGV, has shown promise in identifying new failures and escalating water losses, which is crucial for effective predictive maintenance. Implementing timely evaluations of the water supply system's status can lead to substantial savings in lost water, highlighted by analyses of two simulated scenarios. By merging three critical concepts into the comprehensive WALEGRIN 4.0 model, this approach enhances management processes within water supply organizations.

The integration of Lean and Green principles, along with digital advancements based on Industry 4.0, has refined traditional water supply practices. This paper's insights and outcomes aim to facilitate smoother and more practical changes for water supply organizations, enhancing their efficiency supported by established and recommended KPIs. The WALEGRIN 4.0 model is adaptable to any public water supply organization.

The study revealed that most respondents have served for over four years. It identified a well-defined organizational structure within the company, effectively reflecting the chain of command, with clear lines of authority and responsibility established to ensure compliance with company policies and procedures in the control environment. The findings indicate that management addresses variances between actual and projected financial performance promptly, highlighting strong practices regarding control activities. Most respondents concurred that the company conducts both internal and external audits promptly. Additionally, the findings suggest that communication aids in assessing the effectiveness of the organization’s guidelines and policies. A significant number of respondents agreed that management regularly reviews internal control systems. The results indicate that performance, control environment, control activities, risk assessment, information and communication systems, and monitoring significantly impact the performance of water companies in Croatia. The study concluded that a more effective control environment correlates with higher performance levels in these companies. Furthermore, the findings underscore a robust relationship between internal controls and the performance of water companies in Croatia. It was determined that once the level of internal controls used by water companies is understood, it becomes easier to predict their performance.

6.2. Recommendations for Future Research

Future research will focus on enhancing the predictive analytics of monitored water consumption to improve visibility and provide timely, reliable indicators of changes in the water supply system. These changes may signal instability caused by increasing water losses and the onset of new failures. As the International Water Association (IWA) recommended, water loss management can be strategically approached through four distinct action directions. This paper examined the potential for boosting the efficiency of public water supply by implementing the WALEGRIN 4.0 model for active water loss management. Future research will also analyze the applicability and impact of the comprehensive WALEGRIN 4.0 model on the other three strategic action directions.

The study recommends that a study be undertaken on the factors affecting the size of Water service providers under Kenyan water companies' service boards. The study was confined to water service providers in Kenyan water companies; on internal controls on the performance, further study should be undertaken on other water service providers in the water services board and other firms in different industrial sectors. The role of internal controls on the financial performance of water companies should also be studied. Also, a study needs to be conducted to assess critical dimensions of the relationship between internal control and its effect on water companies' performance in a predefined environment regarding social, religious, environmental, and political considerations.

6.3. Conclusion

In conclusion, the integration of robust internal controls within the WALEGRIN 4.0 model significantly enhances the operational efficiency of public water supply organizations. These organizations can optimize their technical efficiency and ensure sustainability by prioritizing the analysis of absolute and relative water losses—vital KPIs for business success. The strategic zoning of the water supply system, complemented by the introduction of DMA zones for effective water loss management, exemplifies best practices in the industry. Furthermore, embracing industry 4.0 technologies fosters the evolution toward innovative water supply systems, ultimately leading to improved economic recovery. Therefore, a concerted focus on internal controls is essential for maximizing the performance of water supply systems and safeguarding crucial resources for communities worldwide.

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