

A Work Project presented as part of the requirements for the Award of a Master's degree in
Management from the Nova School of Business and Economics.

EVALUATING WATER QUALITY MANAGEMENT DRIVERS OF THE MAIN WATER
SERVICE OPERATORS IN PORTUGAL

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Abstract

In Portugal, as everywhere else, water management ecosystem faces emerging challenges, including climate change, resource scarcity, and infrastructure limitations. This work project analyses the key drivers of water service quality model proposed by the Portuguese water management regulation authority (ERSAR). By examining interdependency among the drivers in using a Partial Least Squares Path Modeling (PLS-PM), the study aims to provide a deeper understanding of the factors influencing water service performance.

Key Words

Water, quality, management, supply, PLS regression model, drivers, indicators, service quality, sustainability, global warming, resource scarcity

This work uses key performance indicators measured by the ERSAR (Water and Waste Services Regulation Authority in Portugal) during year 2022.

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1. introduction

Ensuring access to clean water and sanitation is a global priority, as highlighted in the **United Nations Sustainable Development Goal 6** (SDG 6) (Martin, 2023). The access of qualitative water is one of the key factors to ensure public health and economic stability of the countries. Moreover, water management efficiency is also closely related to the environmental protection, which nowadays represents an essential component in the countries' development.

However, the worldwide water system faces increasing pressures and challenges related to climate change, urbanization and resource scarcity (Un-Water, n.d.). The arise of these challenges underscores the importance of a robust governance strategy and regulatory framework that ensure the reliability and the sustainability of the water services in the countries.

Over the past years in Portugal, modernization of the water systems and the water management framework has become increasingly important. Because of the necessity to adhere to the European union directives, the country is making a constant effort to enhance its existing installations. Despite this advancement, the country still faces important challenges, particularly in extending equitable water access to rural and low-density regions, where infrastructure limitations pose significant barriers (Ionexchange. 2024).

To address to the actual challenges described earlier, the study of the **water supply service quality** becomes an essential tool. Indeed, analyzing the key drivers that explain the service quality dynamics will clarify the different influences and relationships that compose the actual model. A better understanding of the global model structure will permit the water management operators to focus on the most critical aspects highlighted in the model evaluation.

This work project aims to analyze the key drivers of water service quality in Portugal, focusing on its interconnected dimensions. After a complete literature review that will permit to understand the global structure, as well as the trends and challenges of the Portuguese water

management sector, we will perform a statistical analysis (PLS-PM), that will permit to describe the correlations of the different categories of the service quality management. This study will require the use of a large set of data, measuring different key performances of the water supply operators. The **ERSAR** (Water and Waste Services Regulation Authority) will provide a comprehensive dataset needed for this analysis, including the key performance indicators collected from the operators across Portugal.

2. Literature review

2.1 Overview of Water Management in Portugal

This section explores the primary stakeholders, the governance structures and the challenges and priorities of the country's water management landscape.

In Portugal, the water management ecosystem is composed of many different stakeholders. This sprawling system not only involves national and local governments but also private operators and companies that are working closely with the authorities (COR–Portugal–Water Management. n.d.). To regulate this complex system the ERSAR plays a crucial role in regulating and supervising water supply. The key role of ERSAR is to ensure that operators meet water quality and accessibility standards in compliance with the strict Portuguese and European regulations, which are constantly evolving (ERSAR - Purpose of regulation. n.d.).

A concrete example of the constant evolution of the sector is the implementation of the national strategic plan PENSAAR 2030 (Strategic Plan for Water Supply and Sewerage Services, an extension of PENSAAR 2020), approved in 2023 by the Portuguese government (Comunicado do Conselho de Ministros. 2023). This new regulation, clearly aligned with EU directives such as Water Framework Directives focuses on efficiency, sustainability, and the economic valorization of the water services (Directive - 2000/60 - EN - Water Framework Directive - EUR-LEX. 2014). This plan also proposes key actions and ideas to support the improvement

of universal access to water in Portugal. Indeed, the country still struggles to ensure access to high-quality and affordable water supply in rural and low-density areas, which are often struggling with infrastructure limitations (Ionexchange. 2024). This lack of facilities tends to be compensated with the implementation of innovative water management solutions, such as decentralized wastewater treatment and controlled individual systems (Macedo, C., & Macedo, C. 2022). Finally, for low-income households, social tariffs and subsidies are in place to reduce economic barriers, ensuring that water remains an accessible resource (Teixeira, O. 2024).

2.2 Portugal's Laws for Water Quality and Service Standards

To effectively manage the operational system outlined in the previous section, a strong and comprehensive legal framework is needed. This section will explore the most recent key principal regulations that shape the Portuguese legal framework.

A cohesive legal framework for water quality and services

In 2009 Portugal established a solid legal foundation for water quality regulation by implementing **Decree-Law No. 194/2009**. This law assigns municipal services responsible for ensuring compliance with national and European standards for water supply, wastewater sanitation, and urban waste management (Diário a República, D. 2009). It also mandates that service providers share publicly detailed information about water quality to foster transparency and public trust. Another important regulation is the **Decree-Law No. 152/2017**, which is the most recent law that determines the minimum water quality standards for human consumption. This amendment ensures that every Portuguese citizen has access to clean water and minimizes to nearly zero the risk for people to consume non-drinkable water (Diário da República, D. 2017). These two decrees are only a small example of all the laws that form the core legal structure of water quality and services standards in the country. To wrap up, we can state that

safe water delivery is not only a matter of quality assurance but also operational reliability, requiring effective infrastructure management and maintenance.

Integration of Environmental Protection

Portugal's water legislation also emphasizes environmental sustainability, particularly through the mandatory use of **Environmental Impact Assessments (EIA)**. For projects like treatment plants or new pipelines, EIAs evaluate potential ecological risks and propose measures to mitigate environmental harm. This legal mechanism ensures that infrastructure development aligns with conservation goals and minimizes ecosystem disruption (Environmental impact assessment. n.d).

Building on this foundation, **Decree-Law 119/2019** reinforces Portugal's commitment to sustainable water use by encouraging the reuse of treated wastewater, especially in the agriculture and industrial sectors (Diário da República, D. 2019). This initiative not only reduces the strain on freshwater resources but also aligns with the EU's Water Framework Directive (Directive - 2000/60 - EN - Water Framework Directive - EUR-LEX. 2014).

The Role of ERSAR: Bridging Compliance and Oversight

ERSAR, (Water and Waste Services Regulation Authority) is an independent and impartial and transparent organization that ensure the ensure the regulation of the water and waste services in Portugal. The organism plays a critical role in ensuring compliance with the country's legal framework. It monitors water providers' adherence to service quality standards, manages performance indicators, and enforces penalties when violations occur. These actions are important both to guaranty a physical and economical accessibility of water to the Portuguese citizens, and to stimulate an effective right to information regarding water management practices (ERSAR - Mission. (n.d)).

2.3 ERSAR Performance Indicators for Measuring Service Quality

ERSAR has developed a comprehensive framework that measures over 170 key performance indicators to ensure the quality, reliability, and sustainability of water services in Portugal. To meet the principles outlined in **ISO 24500** (the international standards that focuses on accessible designs for auditory management) (ISO 24500:2010. n.d.), ERSAR structured its assessment system into three key categories: **Adequacy of service to the user, Operator sustainability, and Environmental sustainability** (ERSAR Technical Guides. (2023).

Adequacy of the Service to the User

This category highlights ERSAR's commitment to ensuring that water services meet user expectations in terms of accessibility, affordability, and quality. Recognizing water as a universal right, this dimension emphasizes that services must be provided equitably across all regions and socioeconomic groups, reducing disparities in access. Affordability is a critical focus, ensuring that low-income households are not disproportionately burdened by water costs, aligning with Portugal's broader social equity goals (Teixeira, O. 2024). Finally, in controlling the water quality by performing routine controls or more intense inspections, ERSAR minimizes the risks of a possible supply to the inhabitant a water that would not respect the quality norms.

Operator Sustainability

The long-term reliability of water services depends on the operational sustainability of service providers. This category assesses how effectively operators maintain their infrastructure, including pipelines and other critical systems, to avoid service disruptions and minimize water losses. It also examines the capacity of operators to manage their resources efficiently, implement preventive maintenance practices, and quickly respond to emergencies, ensuring continuity of service and reducing the risk of operational failures.

Financial sustainability is also crucial. By evaluating the ability of operators to cover costs and invest in necessary upgrades, ERSAR ensures that utilities remain viable without compromising affordability for consumers. This category reflects a broader commitment to resilience, as operators must be prepared to respond to external pressures, such as climate change or demographic shifts, without compromising the quality of service.

Environmental Sustainability

Environmental sustainability ensures that water services align with ecological priorities and comply with national and EU environmental standards. Conservation efforts, like reducing water losses and promoting the reuse of treated wastewater, are essential for combating water scarcity and adapting to climate change.

Energy efficiency is another critical focus area, particularly in reducing the carbon footprint of water and wastewater treatment operations. ERSAR encourages the adoption of energy-efficient technologies to not only lower operational costs but also contribute to the global climate goals (Fischer A. 2021). Proper wastewater discharge and pollution control are equally important, ensuring that water services do not negatively impact natural ecosystems.

2.4 Synergies and dependencies among water management dimensions

Although ERSAR has categorized its most important performance indicators into the three distinct dimensions developed in the previous part, these categories are not isolated. In this section, we will focus on the most important links that illustrate how these dimensions interact and influence each other.

Environmental Sustainability: A Driver of Operator Sustainability and Service Adequacy

First, environmental sustainability is now a requirement for the good financial and operational health of the operators. Indeed, the safeguarding of water sources from pollution and the implementation of sustainable water extraction practices are crucial for the operators, enabling

them to mitigate challenges such as elevated treatment costs or resource shortages (Global water forum. 2023). Moreover, the rise of climate-related events, such as droughts and floods, forces operators to implement adaptive strategies, so they can be able to consistently provide reliable services over a long-term perspective.

Environmental sustainability also directly impacts the quality of services offered to users. As we know, managing natural resources responsibly is imperative to supply the population a clean drinking water. Furthermore, population awareness of global warming and water management challenges is steadily increasing, making adherence to environmental standards increasingly important for the brand image of operators (European Investment Bank. 2024).

Operator Sustainability: A Foundation for Service Adequacy

As mentioned in the previous parts, the operators' financial and operational sustainability is vital to propose high service quality to all the customers. First, the key for the operators is to be able to propose a continuous supply of drinking water to the customers. Every supply interruption has huge effects on the operator, both on its public image and its financial revenues. To ensure sustainable development and financial revenues, the operator must consider public confidence. This involves strict care of the water treatment installations and regular testing of the water to ensure its high-quality. Furthermore, the ability of the operators to supply reliable water not only in urban areas but also in underserved areas improves a lot the public vision of the company. Finally, the ability of the operators to deal rapidly and adequately with unexpected challenges, such as equipment failure or environmental stresses, is a determinant regarding the customer confidence to the services.

2.5 Partial Least Squares Path Modeling (PLS-PM): A methodology to understand water management dynamics

This statistical methodology is used to analyze complex relationships between latent variables, which are constructs that are not directly measurable but are inferred through observable and measurable indicators. This model can handle non-normal data and is very flexible regarding data management (Sanchez G. 2013). The PLS model is composed of two key models. First, the **structural (inner) model** specifies the relationships between the latent variables themselves. The inner model must be predefined, based on the study of the possible relations. Then, the **measurement model** examines the relationships between the observed indicators and their associated variables. The analysis of the measurement model permits to understand the correlations between the latent variables (Sanchez G. 2013).

The PLS-PM also permits to handle both **formative** and **reflective** measurement models. The reflective model (standard in a PLS study) assumes that the variation of the indicators is caused by the inner model construction. On the other hand, a formative model permits to define the inner model based on the indicators measured (Sanchez G. 2013). Finally, to combine both reflective and formative measurement, it is possible to perform a **MIMIC** (Multiple indicators, multiple causes) model. This approach is particularly useful for capturing the broader influences on a latent variable while still measuring its observable manifestations (Sanchez G. 2013).

3. Problem statement

As highlighted in the literature review, water management in Portugal faces a delicate balance between sustainability, operational efficiency and service delivery. Even if the country has a robust legal framework and a competent regulatory authority (ERSAR) that monitors key performance indicators, Portugal continues to encounter challenges in meeting user expectations for water services, particularly in rural areas or in the management of the rising

frequency of climate change-related events. The interdependency among environmental sustainability, operator performance and service adequacy remain complex and underexplored. The understanding of the dynamics between these three drivers could permit to provide concrete and actionable insights to enhance the operational strategies of the sector.

4. Research objective

The purpose of this research is to create an accurate model that will explore and quantify the relationship between the key drivers of water management in Portugal: environmental sustainability, operator sustainability and adequacy of the service to the user. The analysis seeks to identify the influence each dimension exerts on the others. Ultimately, the findings will offer recommendations for policymakers and operators to enhance service delivery and quality, to promote a more sustainable operation management, and to strengthen operational resilience to the evolving challenges.

Research question: How do environmental sustainability, operator sustainability, and adequacy of the service to the user interact within the water management framework?

5. Methodology

5.1 Data collection

The data we will use to pursue this study was collected from the official website of ERSAR. The regulation authority provides for every year all the data of the key performance indicators measured during the year in all the water treatment companies of Portugal. Because data of year 2023 wasn't available at the beginning of the study, we chose to focus on the dataset of **2022**. Moreover, even if ERSAR proposes data for both water supply and wastewater management, we decided to focus the research on the data from public water supply, excluding wastewater management. In fact, because our study focuses on service quality offered to the user, we think

that wastewater management should be analyzed separately. Finally, because we are focused on service quality and customer satisfaction, we will focus our research on the companies that are evolving with the system type **Baixa (retail)**. This system type refers to the companies that are distributing water to the clients and are responsible of the local maintain of the infrastructures. The companies that are evolving in the system type **Alta (bulk)** (water production and transportation to the “Baixa” companies and large-scale infrastructure management) will not be mentioned in our study.

The model developed in this study uses three key drivers: Adequacy of the service to the user, Operators sustainability and Environmental sustainability. These drivers reflect the key dimensions ERSAR uses to classify its most important key performance indicators. This classification, aligned with ISO 24500 (focused on water services) and ISO 55000 (asset management), is based on both past experience and future strategic plans (PENSAAR 2030), and permits a comprehensive understanding of the sector’s objectives.

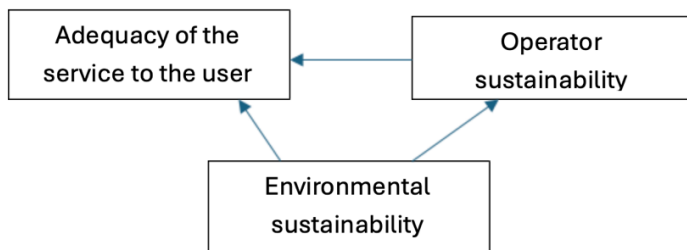
In relation with these three drivers, ERSAR proposes in its model some quantitative key indicators related to each driver (Appendix A). Based on that, we constructed a model with some of the proposed indicators for every driver, excluding the ones with incomplete measurements or that were not coherent regarding our research. On top of that, we decided to add to the model some qualitative data, that we added in the classification of the drivers.

To conclude, the dataset is composed of data from 219 companies, divided in three main categories: Adequacy of the service to the user (5 indicators), Operator sustainability (5 indicators) and environmental sustainability (4 indicators). The indicators’ repartition is detailed in Appendix B, and their names in the models is detailed in Appendix C.

5.2 The modeling process

To perform the analysis of the data and the running of the PLS analysis we used the programming tool R. First, based on the observations from the literature review and the data collection, we decided to construct the following inner model (Figure 1): Operator sustainability and Environmental sustainability influence Adequacy of the service to the user, and Environmental sustainability influences Operator sustainability.

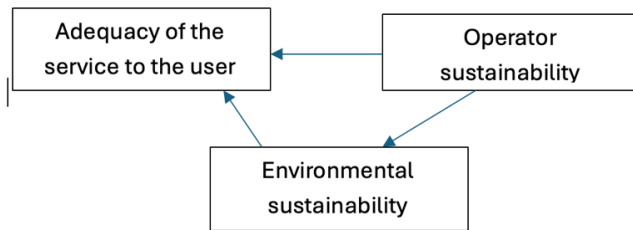
Figure 1: Inner model V1



The outer model uses the indicators' classification described in Appendix B and Appendix C. First, we run a standard PLS model, where the three manifest variables of the inner model are reflective of the outer model. After the first run of this reflective model, a decision was taken to pursue the analysis using the MIMIC (Multiple effect indicator for multiple causes) model. This new model will permit to capture the multidimensional nature of the study, and how some exogenous variables have an influence on the entire inner model. It will then permit to capture additional pathways from causes and outcomes.

Then, we performed another MIMIC analysis but with an updated inner model (Figure 2): Operator sustainability and Environmental sustainability influence Adequacy of the service to the user, and Operator sustainability influences Environmental sustainability.

Figure 2: Inner model V2



This model permitted to explore another relationship between latent variables and may challenge the relationship hypothesis developed in the literature review.

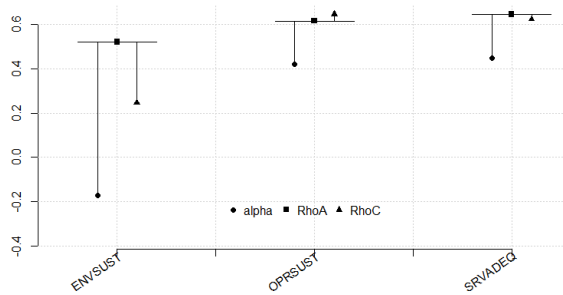
Finally, two last models have been run, with the original inner model as drivers' structure (Figure 1). First, we run a MIMIC model without the variables that were candidate for exclusion (Appendix F). For the last model, we tried to add some indicators related to Operator sustainability, that were excluded from the first indicator selection (Appendix G). This could permit to enhance the existing model.

6. Results in interpretations of the PLS analysis

6.1 The reflective model

Unidimensionality: Here, the goal is to assess whether the indicators align cohesively to measure their respective latent variables: environment sustainability (ENVSUST), Operator sustainability (OPRSUST), and adequacy of the service to the user (SRVADEQ). A key measure of this alignment is the **Cronbach's Alpha**, which evaluates internal consistency within each latent variable block. Upon examining the results, Cronbach's Alpha values for all constructs fall well below the acceptable threshold of 0.7 (Figure 3). For the latent variable ENVSUST, a negative value of Cronbach's Alpha demonstrates a very poor reliability of the variable. With a Cronbach's Alpha of 0.4, OPRSUST and SRVADEQ also tends to reflect weak internal consistency between the latent variables.

Figure 3: Rplot Reflective model



Outer loadings and communality: The analysis of indicator loadings and communality provides deeper insights into the performance of individual indicators. Outer loadings measure the strength of the relationship between each indicator and its latent variable, while communality assesses the variance of each indicator explained by its latent variable.

In this reflective model, several indicators have outer loadings significantly below the acceptable threshold of 0,7, with some even falling below 0,4 (Appendix D). The indicators with a loading value under 0,4 are candidates for exclusion or revision, as their weak contributions undermine the explanatory power of the model.

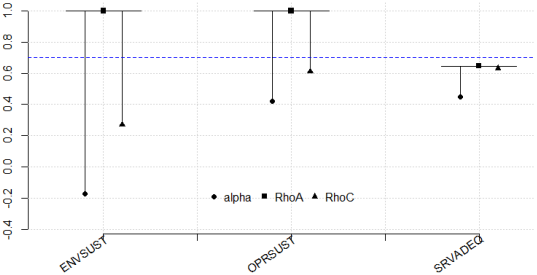
Moreover, the **Average Variance Extracted (AVE)** metric is likely well below the recommended threshold of 0.5 for all constructs, implying that the indicators fail to capture at least 50% of the variance in their constructs. These low AVE could support the likelihood of multidimensionality among the 3 latent variables.

6.2 The MIMIC V1 model

As underlined in the previous part, the results given by the reflective model are not satisfying. By performing a MIMIC model, we will try to improve the reliability of the drivers and the performance of the drivers.

Unidimensionality: After running this new model, we found three Cronbach's Alpha variables that are similar with the ones founded in the reflective model. The most important change added in this model is the improvement of (ρ_A) coefficient for both ENVSUST and OPRSUST (Figure 4). Even if this could appear to be an improvement on the model, this improvement needs to be shaded. In fact, this improvement could indicate overfitting in the model due to constrained or excessively optimized indicator weights. This often happens in small or highly correlated indicator sets, where the algorithm produces extreme loadings to maximize reliability.

Figure 4: Rplot MIMIC V1



Outer loadings and commnality: As shown in Appendix E, we do not observe important changes in the loading of the indicators. This new model still shows the weakness of Real water losses (AA15b), connection to the service (AA07b), Main rehabilitation (AA09b), Service coverage (AA01b) and Affordability of the service (AA02b). These variables continued to display negligible loadings, and remained non-significant, offering little contribution to their constructs. These poor loadings also affect the AVE, which is still below 0,5 for all the constructs of the model.

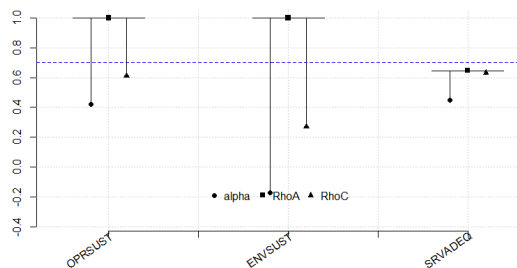
6.3 The MIMIC V2 model

Before making some important changes in the data used to create the models, we decided to run one last model with the current data but with a changed inner model. In this model, we have

switched the path of influence between Operator sustainability and Environmental sustainability (Figure 2).

After analyzing the results of this second MIMIC run, we can conclude that we did not observe any improvements in reliability metrics (Figure 5), indicators' loadings or communality.

Figure 5: Rplot MIMIC V2



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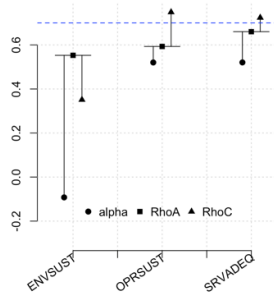
The structural movement in the inner model did not affect the strength and the reliability of the model

6.4 The MIMIC V3 model

During the run of the previous models, we remarked that some indicators were considered as “weak variables”, with loadings values under 0,4. We decided to run a new model, excluding these problematic variables (Appendix F) to see if we can observe notable changes in the outputs.

Unidimensionality: we observe a slight improvement of the Cronbach's Alpha for both OPRSUST and SRVADEQ, with both values equal to 0,52 (Figure 6). This improvement underline the growing importance of these two drivers in explaining the model. However, ENVSUST coefficient value remains very low, with a negative Cronbach's Alpha (-0,092), indicating severe internal consistency issues.

Figure 6: Rplot MIMIC V3



Outer loadings and communality: We can observe that now all the loadings except AA01b, are exceeding 0,4 (Appendix G), which is a good improvement compared to the previous models. Because we are conducting research, we will accept the loading levels above 0,4, even if the usual threshold is 0,7. Moreover, we can observe a slight increase of the AVEs for the three drivers compared with the MIMIC V2, with AVE of OPRSUST exceeding the threshold of 0,5. OPRSUST now explains more than 50% of the variance in its indicators, demonstrating a notable improvement for the validity of this construct. This global improvement strengthens the reliability of all the constructs, and the robustness of the model.

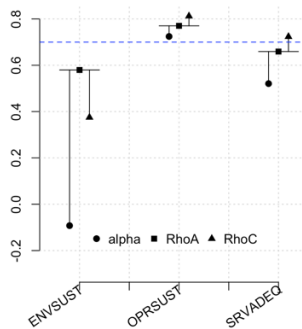
6.5 MIMIC V4 model

Now that we excluded the weakest variables of the model, we will try one last run of the model using new indicators. In fact, during the indicators' selection, we preselected some indicators related to OPRSUST that were eventually excluded from the final dataset. By incorporating these indicators, we aim to increase the reliability of OPRSUST, and more broadly the robustness of the entire model.

Unidimensionality: The integration of the 3 new indicators has had a positive effect to the model. Indeed, with an increase of its Cronbach's Alpha to 0,72 (Figure 7), OPRSUST can now be considered as a strong construct in our model. For both ENVSUST and SRVADEQ drivers we do not observe significant changes compared to MIMIC V3. This result was expected since

we did not add any indicator related to these constructs, as there was no more reliable key performance indicators measured that feet into these two categories.

Figure 7: Rplot MIMIC V4



Outer loadings and communality: The three new indicators added have acceptable loadings results, with one above 0,7 and the two others above 0,4 (Appendix I). We can state that adding these indicators had a positive impact on the construct OPRSUST’s reliability. However, the AVE of the driver slightly dropped compared to its value in MIMIC V3, with a result of 0,429 that is now above the 0,5 threshold. This drop weakens the driver’s ability to explain the indicators’ variance. Nevertheless, it is important to mention that the AVE values of all three constructs are not fare from the acceptable threshold, with all values included between 0,42 and 0,44.

6.6 Process analysis and Final Reflections

The iterative modeling process, from the reflective model to MIMIC V4, allowed us to progressively improve the reliability and robustness of the constructs while uncovering important insights. By addressing the weaknesses observed in the initial reflective model—such as low indicator loadings, poor reliability, and weak Average Variance Extracted (AVE) values—we transitioned to MIMIC models that better capture the multidimensional nature of the constructs.

Overall, the driver Operator sustainability is the one that showed the most significant improvements, ending as the most reliable construct of the model. However, to empower the driver in the model, we had to exclude two indicators that were initial components of the ERSAR model, replacing them with other key performance measures that don't appear in the initial model.

With a Cronbach's Alpha above 0,4 in the last run model, the Adequacy of the service driver offered acceptable results regarding its reliability in the model. To improve the construct's robustness, we deleted an indicator that was initially included in the ERSAR model, as we did for the Operator sustainability.

In every run of the model, the Environmental Sustainability construct consistently exhibited a negative and near-zero Cronbach's Alpha, indicating significant issues with internal consistency. Even after removing the indicator with the poorest loading, the construct's reliability did not improve, suggesting it does not contribute meaningfully to the overall model. This result questions the choice of ERSAR regarding the indicators used to explain the Environmental sustainability driver.

Among the relationships tested in the structural model, the only relationship that consistently demonstrated strength is the influence of Operator sustainability on the Service adequacy to the user. As stated in the inner model, improvements in the Operator sustainability have direct and positive impacts on the Service adequacy.

7. Conclusion

7.1 Limitations

During this study, we encountered several limitations. First, to conduct a focused study, the analyzed dataset has been confined to retail public water supply, omitting wholesale (bulk) operators. Additionally, the study does not address wastewater management, which is a key component of the water management sector. To facilitate calculations and model development, the study relied solely on data from 2022. Incorporating multiple years of data could offer a more dynamic perspective and highlight trends over time. Lastly, we faced struggle in managing indicators that had uncomplete dataset or incompatible measure unit with the model. This reduced drastically the number of indicators used for every driver.

7.2 Result analysis and recommendations

The results of this study underscore the critical role of the sustainability of the water supply operators in Portugal. This sustainability is a central component of the Service adequacy to the users. On another hand, the environmental sustainability impact remained difficult to measure and understand, as the indicators used in the model failed to construct a reliable driver in the model. Based on these observations, it could be interesting for ERSAR to start a full review the supply service quality indicators model. First, as mentioned in the limitations, the completeness of data for several indicators could help to better analyze the entire proposed model. Moreover, a focus on the reliability of the indicators that refer to the Environmental sustainability driver will be necessary, as the actual key measurements fail to construct a reliable category.

7.3 Directions for future research

The future research should first focus on the identified limitations. The purpose of a future study will be to consider the global water management field, in conducting the study with a multiple

year database, to allow the analysis of trends, seasonal variations and the long-term impact of policy changes.

Moreover, it could be interesting to integrate new key categories to the water supply service quality model. This improvement could permit to integrate new key performance indicators measured, that are today not classified in any of the three categories. Then, new links could be discovered among indicators or categories, making the quality of service measurement model more powerful and accurate.

8. Appendix

Appendix A: ERSAR Water supply service quality indicators for Retail

Adequacy of the service to the user
AA01 – Service coverage (%)
AA02 – Affordability of the service (%)
AA03 – Service interruptions [number/(1000 service connections · year)]
AA04 – Safe water (%)
AA05 – Response to complaints, suggestions and information requests (%)

Operator sustainability
AA06 – Cost recovery(%)
AA07 – Connection to the service (%)
AA08 – Non-revenue water (%)
AA09 – Mains rehabilitation (%/year)
AA10 – Mains failures [number/(100 km · year)]
AA11 – Adequacy of treatment capacity use(%)
AA13 – Adequacy of human resources in water treatment [number/(10 ⁶ m ³ · year)]
AA14 – Adequacy of human resources in water distribution [number/(1000 service connections · year)]

Environmental sustainability
AA15 – Real water losses [m ³ /(km · day)]
AA15 – Real water losses [l/(water connection · day)]
AA16 – Energy efficiency of pumping facilities [kWh/(m ³ · 100 m)]
AA17 – Treatment sludge production[kg/m ³]
AA18 – Self-produced energy (%)

Appendix B: Model dataset

Adequacy of the service to the user				
Service coverage	Affordability of the service	Safe Water	Supply failures	Accommodations served
%	%	%	n. ^o /year	n. ^o

Operator sustainability				
Connection to the service	Mains rehabilitation	Certification of quality management systems	Management model	Intervention area
%	%	Qualitative	Qualitative	Qualitative

Environmental sustainability				
Real water losses	Energy efficiency of lifting installations	Certification of environmental management systems	Energy efficiency plan	
l/(water connection · day)	kWh/(m ³ ·100m)	Qualitative	Qualitative	

Appendix C: Indicator codes in the model

Service coverage	AA01b
Affordability of the service	AA02b
Safe Water	AA04b
Supply failures	PdAA041b
Accommodations served	PdAA019b
Connection to the service	AA07b
Mains rehabilitation	AA09b
Certification of quality management systems	PdAA092b
Management model	PdAA002b
Intervention area	PdAA025b
Real water losses	AA15b
Energy efficiency of lifting installations	AA16b
Certification of environmental management systems	PdAA091b
Energy efficiency plan	PdAA098b

Appendix D: Indicators' loadings in the Reflective model

	ENVSUST	OPRSUST	SRVADEQ
AA15b	-0,009		
AA16b	-0,5		
PdAA091b	0,877		
PdAA098b	0,564		
AA07b		0,299	
AA09b		0,152	
PdAA092b		0,802	
PdAA002b		0,416	
PdAA025b		0,819	
AA01b			0,31
AA02b			-0,093
AA04b			0,533
PdAA041b			0,713
PdAA019b			0,88

Appendix E: Indicators' loadings in the MIMIC V1 model

	ENVSUST	OPRSUST	SRVADEQ
AA15b	0,015		
AA16b	-0,405		
PdAA091b	0,949		
PdAA098b	0,446		
AA07b		0,194	
AA09b		0,094	
PdAA092b		0,789	
PdAA002b		0,421	
PdAA025b		0,860	
AA01b			0,327
AA02b			-0,073
AA04b			0,534
PdAA041b			0,715
PdAA019b			0,878

Appendix F: Indicators excluded for MIMIC V3 and MIMIC V4

Indicators excluded for MIMIC V3 and MIMIC V4			
Affordability of the service	Connection to the service	Mains rehabilitation	Real water losses
%	%	%	l/(water connection · day)

Appendix G: Indicators' loadings in the MIMIC V3 model

	ENVSUST	OPRSUST	SRVADEQ
AA16b	-0,487		
PdAA091b	0,891		
PdAA098b	0,547		
PdAA092b		0,814	
PdAA002b		0,465	
PdAA025b		0,81	
AA01b			0,33
AA04b			0,554
PdAA041b			0,705
PdAA019b			0,876

Appendix H: Indicators added for MIMIC V4

Indicators added for MIMIC V4		
Certification of occupational health and safety management systems	Pumping stations	Water safety plan
Qualitative	Number	Number

Appendix I: Indicators' loadings in the MIMIC V4 model

	ENVSUST	OPRSUST	SRVADEQ
AA16b	-0,451		
PdAA091b	0,901		
PdAA098b	0,553		
PdAA092b		0,777	
PdAA002b		0,484	
PdAA025b		0,695	
PdAA093b		0,804	
PdAA032b		0,46	
PdAA099b		0,627	
AA01b			0,32
AA04b			0,551
PdAA041b			0,715
PdAA019b			0,875

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