LA CRISIS DEL AGUA EN EL SIGLO XXI: PERSPECTIVAS Y SOLUCIONES

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LA CRISIS DEL AGUA EN EL SIGLO XXI: PERSPECTIVAS Y SOLUCIONES

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FASCÍCULO 6
SANEAMIENTO Y TECNOLOGÍAS

Carlos Alberto Ávila Orta
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A GOVERNANCE ANALYSIS OF THE ROLE OF ARTIFICIAL INTELLIGENCE IN THE EUROPEAN WATER SECTOR

Cesar Casiano Flores
A. Paula Rodríguez Müller

Abstract

Digitalisation in the water sector is expected to address water-related challenges and support Europe's Twin Transition (digital and green transition). However, there is a limited understanding among users and providers of digital public services regarding the specific conditions and complexities of digitalisation, innovation and water from a governance perspective. To increase our governance understanding on those subjects, we have selected three cases where artificial intelligence has been implemented in the water sector. The analysis uses the *who-how-what* analytical framework within the hierarchy, market, and network governance modes approach. We analyse and triangulate information obtained via secondary sources to achieve this objective. The analysis provides insights into the actors driving collaborative governance strategies to foster innovation. In the Netherlands case, we found a market approach; in Portugal, a mixed mode that combines hierarchical and network modes; and in the Polish case, a hierarchical mode. Despite the differences in the three cases, governmental actors play a key role, ranging from facilitating coordination and co-funding to direct involvement. Moreover, all the cases had a narrow innovation focus on environmental technologies to drive sustainability. Understanding the limitations of our research, we propose, as a next step, to conduct an

in-depth case analysis, including primary sources of data. We also invite future research to expand the understanding of the complex interplay between disruptive technologies, innovation, and governance in the water sector.
Key words: water governance, artificial intelligence, Europe.

Introduction

Water governance remains at the core of sustainable development, especially as water resources face escalating pressures from factor such as population growth, economic development, and climate change (Özerol et al., 2018). Against this context, the imperative for effective water management has never been more critical. Ensuring sustainability demands a coordinated approach that integrates the development and management of surface water, groundwater, and land use at a hydrological basin level. To navigate these challenges, the European Union (EU) has implemented the Water Framework Directive (EU WFD) (EC WFD, 2000). This landmark legislation underscores the importance of river basin management, engaging in extensive consultation and coordination with all stakeholders, and robustly applying the "polluter pays" principle. Alongside the Environmental Quality Standards Directive for surface waters and the Groundwater Directive, the EU WFD has sculpted the framework for sustainable water management across Europe since the early and mid-2000s (European Commission, 2022).

Despite efforts to address Europe's varied water issues, there is still much work to be done. Policy coordination and coherence are crucial but often difficult to achieve (Jager, et al. 2016). Digitalisation has emerged as a promising solution, as it has the potential to make water policy more mainstream and enable more effective actions. For instance, the EU WFD has actively endorsed the integration of Earth Observation and data-driven models into water technologies (Carvalho et al., 2019). Further, the 2019 European Green Deal has underscored the potential of digitalisation to achieve environmental and climate goals, advocating sustainable digital technologies as essential enablers for an equitable green transition (European Commission, 2019). Leveraging digital technologies such as sensor networks, artificial intelligence (AI), and big data analytics, promises to optimise water management, enhance water systems resilience (European Commission, 2023),

promote stakeholder engagement and enable more efficient and sustainable use of water resources (EISMEA, 2021).

In envisioning a water-smart society, the interplay between digital transformation and digital services may immerse the water sector in the data economy paradigm. Emerging technologies, notably AI, have the potential to redefine water governance by enabling better decision-making, improving resource efficiency, and reducing operational costs. Thus, the development and implementation of robust, smart, and tailored water management systems, solutions, and multi-sectoral governance models become essential not only in Europe but globally, to address water-related challenges and align with Europe's Twin Transition (digital and green transition) (European Commission, 2023; Stein et al., 2022).

Yet, despite a promising technological scenario, the water sector needs higher level of maturity concerning the integration and standardisation of information and communication technology (ICT), business processes, and legislative framework implementation. The water sector's fragmented nature, along with limitations in organisational and financial resources, emphasises the need for system standards to enable smart water solutions. These standards can promote common meta-data structures, standard protocols, and interoperable interfaces (European Commission, 2023; Stein et al., 2022). Additionally, there remains a lack of coherence in European policies related to digitalisation in the water sector. Users and providers of digital services also have a limited understanding of water governance conditions (Stein et al., 2022), which presents further hurdles.

This study aims to contribute to this gap, providing a governance modes analysis of cases where disruptive technologies like AI have been employed to innovate in the water sector. The chapter is organised as follows. First, the theoretical framework is discussed, followed by the methodological approach employed in this study. Next, the results are presented per case. Finally, a discussion of the findings and concluding remarks are outlined.

Theoretical framework

The challenges of water crises across the globe are widely recognized as crises of governance (Özerol et al., 2018). This requires a deeper understanding of governance

mechanisms and their role in promoting innovations that can address such crises. In this study, water governance is understood as "the social function that regulates development and management of water resources and provisions of water services at different levels of society and guiding the resource towards a desirable state and away from an undesirable state" (Pahl-Wostl, 2015, p. 25).

Among the different perspectives on water governance, the approach using hierarchy, market, and network modes has gained popularity in the literature on governance. The three modes function as coordinating frameworks (Bouckaert et al., 2010) and are instrumental in understanding how collective issues like urban water management are managed (van de Meene et al., 2011). These frameworks facilitate an analysis of decision-making, implementation processes and the dynamics between participating actors (Meuleman, 2008), recognising that often coexist and overlap (Pahl-Wostl, 2019; Whelan, 2015).

The hierarchy mode primarily concentrates on regulatory procedures based on formal norms and sanctions; moreover, authority, power, and the hierarchy's official position are the steering sources (Pahl-Wostl, 2019). In contrast, the market mode is built on formal and informal institutions. The process and financial incentives serve as the basis for steering. Players are driven to increase their material advantages, and in this situation, power comes from having access to wealth and material resources (Pahl-Wostl, 2019). Lastly, informal institutions dominate the network mode. In this case, trust and voluntary cooperation are the sources of steering, and one's position in the network confers power. The informality and flexibility of the network make it a good platform for learning and modifying processes (Pahl-Wostl, 2019).

While these three modes of governance offer valuable insights into understanding sustainable innovations, they have been criticised for oversimplifying the complexities of governance. Moreover, the intricate interplay between participating individuals, both directly and indirectly involved in the governing process, is often left unaddressed. To enrich this understanding, the study extends the discussion to include the "who", "how" and "what" of sustainable innovations governance (Lupova-Henry & Dotti, 2019).

The first variable ('who') seeks to identify the primary actor responsible for implementing governance strategies for long-term innovation. Three perspectives can be identified within the hierarchy, market and network approach: state-centric, corporate-

centric and society-centric approaches (Lupova-Henry & Dotti, 2019). The question of "how" to govern sustainable innovations ultimately comes down to two fundamental considerations: how much the primary actor engages with stakeholders and what the main approaches are to such engagement (Lupova-Henry & Dotti, 2019). Sustainable innovation governance must consider the third dimension to shed light on "what" is being governed, and for this, two extremes have been identified. The narrower innovation definitions focus on environmental technologies to drive sustainability, while the more holistic approaches emphasise the interaction between sustainability's environmental and socioeconomic aspects (Lupova-Henry & Dotti, 2019).

By considering these dimensions, the theoretical framework provides a nuanced view of water governance, capturing the complexities and interactions, allowing for a more detailed examination of how sustainable innovations can be effectively governed to meet the challenges of the global water crisis.

Methodology

In alignment with the theoretical framework, the methodology for this study employs the *who*, *how*, and *what* structure as a lens to explore the selected cases through the hierarchy, network and market governance modes. This approach is applied to elucidate the various governance configurations evident in the selected cases.

The study relies on a comprehensive desk research approach, drawing on secondary sources including peer-reviewed journal articles, governmental reports, newspaper articles, and relevant websites of involved actors. This wide-ranging data collection enables a nuanced exploration of the national water governance context for each case, followed by an in-depth examination of the case itself.

Recognizing the importance of validity and credibility in research, a systematic triangulation process was employed. Each piece of information was critically analyzed and cross-referenced with other sources to enhance the robustness of the data. This rigorous process ensures that the analysis builds on a solid empirical foundation.

The study's empirical focus lies in the examination of three specific cases selected from a dataset of AI applications in the public sector, compiled by the Joint Research

Centre of the European Commission (European Commission, Joint Research Centre (JRC), 2021). The selection process was carried out in multiple stages:

1. **Preliminary Selection**: 24 cases were initially identified based on the criterion of AI applications in the water context.
2. **Refinement**: Cases still in the pilot phase were excluded to focus on governance configurations that were already materialized, reducing the pool to eight cases.
3. **Relevance Check**: A detailed review of the remaining cases revealed that some were unrelated to water governance, narrowing the sample to four cases.
4. **Final Selection**: In-depth examination led to the selection of one case each from The Netherlands and Poland, and two from Portugal. However, due to insufficient information regarding one Portuguese case, the final selection consisted of three cases.

This selection process allowed a sample of three cases that is both relevant and representative, which form the basis of the analysis presented in the subsequent section.

Results and discussion

This section presents and analyses the results of the study focusing on three selected cases from The Netherlands, Portugal, and Poland. Each case is explored in the context of its national water governance system, highlighting the distinctive governance modes, stakeholders involved, specific projects, and technological innovations. The discussion further interprets the outcomes in light of the theoretical framework, illustrating how each case contributes to our understanding of the governance configurations within the context of water management and AI in the public sector.

The Netherlands

Governance perspective: The Netherlands is indicative of a hybrid governance system where governance modes are balanced and no mode dominates. This is common in countries with effective formal institutions and polycentric governance systems, such as The Netherlands (Pahl-Wostl, 2019). There is decentralisation and coordination of

largely autonomous actors, an approach that has evolved over decades (Pahl-Wostl, 2019). Innovations have emerged from networking of policy entrepreneurs outside the governmental hierarchical structure (Huitema & Meijerink, 2009), and through a positive connection between informal networks and formal policy processes (Pahl-Wostl, 2019). The evolution from a command-and-control approach centred on hard infrastructure measures to a more environmentally conscious approach to an integrated, adaptive approach (Pahl-Wostl, 2019) is also significant in terms of wastewater treatment, where The Netherlands has a very high compliance (OECD, 2020b).

Selected case: The selected project was focused on wastewater management and was a collaboration between the government and HAL24K. HAL24K Labs provides operational and predictive intelligence using cutting-edge data science techniques, like machine learning and deep neural networks, with modelling, analysis, and visualisation to enable real-time data-driven decision-making in complex and multidimensional contexts. The aim is to reduce expenses, minimise disruptions, and maximise resource use (HAL24K Labs, 2022). The platform named Dimension: developed by HAL24K offers tools and capabilities to solve complex challenges and realise operational change. From data ingestion through to predictive planning, Dimension is described as powerful, comprehensive and practical. It supports data-driven decision-making is at hand and operational transformation possible (HAL24K, 2022).

A Dutch Water Boards was the client of HAL24K for predictive maintenance for water treatment plants. The Dutch Water Board have responsibilities on the treatment and cleaning of wastewater and to maintain key infrastructure they monitor different systems via alarms and sensors. Considering that water infrastructure maintenance is complicated, and efficiencies rely on sensors to provide alerts, the Water Board wanted to know if operators could intervene before an emergency occurred. To address this demand, HAL24K built sensor network models using data from sensors, reported alarms, maintenance, and failure logs. As a result, equipment failure can be predicted, proactive maintenance and resource planning can be implemented, and end-of-life management requirements can be met across the network to avoid downtime. This innovation aims to increase operational effectiveness, prolong the useful life of important equipment and reduce expenses (HAL24K, 2018).

In summary, this case involves governmental and private companies, responding mainly to a market collaboration. Regarding how this innovation is governed, the primary actor, which is the Water Board, does not really engage other stakeholders. Finally, in terms of "what", we can assume from the information collected that there is a narrower innovation, which focuses on environmental technologies to drive sustainability.

Portugal

Governance perspective: Portugal's Water Law encompasses various combinations of governance modes, requiring significant institutional efforts and new organisational steps, for which government agencies and stakeholders may be unprepared (Fidélis et al., 2019). They include hierarchical direct management, delegated management, and water service concessions provided by state-owned, municipal, and private entities. There are about 300 utilities, approximately 80% involve direct management, 10% delegated management, and the remaining 10% involve concessions (Baptista, 2019). Multilevel and networked governance is fostering more decentralised administration, reshaping institutional procedures. The recent and gradual delegation of competencies to local and inter-municipal authorities has emphasised this paradigm shift. Yet, networked governance demands complex relationships and stronger ties between various stakeholders (Fidélis et al., 2019). Recent studies highlight that water utilities have begun implemented Water Safety Plans (tools for comprehensive risk management of human consumption water supply) for innovation (Roeger & Tavares, 2020).

Selected project: In Portugal, the identified project is WISDom-Water. Its objective is to implement applications addressing specific water utilities' needs, such as flow rate data processing, determining the best location for pressure sensors, identifying critical distribution network areas for pipe burst location, and prioritizing pipes for rehabilitation (Carriço et al., 2023). The project "developed several artificial intelligence techniques to extract knowledge from the data and to address several WDS [Water distribution system] problems, such as data processing and analysis, pressure sensor location, pipe burst detection and location, pipe condition assessment, and water age performance assessment" (Carriço et al., 2023).

The WISDom-Water project is at the national level and has a partnership with the Empresa Municipal de Agua e Saneamiento de Beja (emas) (WISDom, 2018). This is a water utility that designs, builds and operates water supply and sanitation infrastructures (emas, 2023). Other partners of the project is the company of Infranquinta, which manages the water supply infrastructure in Quinta do Lago and neighbouring resorts as well as collection of urban waste (infraquinta, 2022). Other key stakeholder is the Camara Municipal Barreiro (Barriero City Council) (Câmara Municipal do Barreiro, 2023). Academic institutions like Instituto Politécnico de Setúbal, Instituto Superior Técnico de Lisboa and the Instituto de Engenharia de Sistemas e Computadores: Investigação e Desenvolvimento em Lisboa, are also involved (INESC-ID, 2019). The project is funded by the Fundaçáo para a Ciência e a Tecnologia (FCT) and co-financed with the Instituto Politécnico de Setúbal (FCT, 2018).

In the WISDom-Water project in Portugal, collaboration occurs primarily between water utilities and academic institutions, with financial support provided by FCT. The governance mode of this project appears to be mixed, encompassing both hierarchical structures within government-supported entities and networked relationships between various stakeholders. Regarding the manner in which this innovation is governed, it is evident that the primary actors are confined to those directly engaged in the project. This close-knit collaboration ensures a focused approach towards the project's goals, although it might limit the potential for broader stakeholder engagement. Finally, as for the nature of the innovation itself, analysis of the available information reveals a narrow innovation, which focuses on technological advancements in the environmental sector aimed at enhancing sustainability within water management.

Poland

Governance perspective: In Poland, the complex governance landscape of waterworks and wastewater systems is shared among municipalities, counties, and provincial governments. Municipalities and counties have the primary responsibility for managing these systems, whereas provincial governments oversee the issuance of permits and water use regulation. A river basin management approach was introduced in the late 1980s. Subsequent reforms in 1999 further delineated responsibilities for the river basin

planning and coordination, although significant fragmentation in competencies remains a challenge (Jager et al., 2016). Recently, Poland has witnessed a moderate increase in public participation in water management (Jager et al., 2016), yet governance remains predominantly with financial transfers tightly controlled by the central government (Ferry, 2021). Various institutions shoulder the management of water supply and sanitation, with the National Water Management Authority acting as the overall governing body. At the local level, municipalities (gmina) are responsible for water supply and wastewater collection infrastructure (OECD, 2020a). In terms of wastewater, Poland's decentralised system comprises 3278 municipal wastewater treatment plants, with public urban wastewater treatment systems reaching less than 80% of the population (Kacprzak & Kupich, 2021).

Selected project: The identified project in Poland is entitled "Monitoring of Water Treatment Stations" and falls under the purview of the Ministry of Digitalisation (2023). Specifically targeting the Kartuzy Water Treatment Plant, the initiative emphasises an array of operational aspects including the measurement of flow rate and network pressure, control and regulation of intake operation, and monitoring of water distribution. Additionally, it seeks to balance the volume of water distributed to the network, such as tracking water loss. The project has been implemented in the city of Kartuzy as part of the actions of the Ministry of Digitalisation.

In evaluating this case, collaboration is observed between governmental actors within a governmental project. Characterized by its hierarchical mode of governance, the interaction between local and national governments is evident. As such, innovation is governed strictly by these governmental actors, emphasising a central authority's role. Finally, drawing parallels with the previous cases, the information presented leads to the conclusion that there is a narrow innovation focus on environmental technologies to drive sustainability.

Conclusions

This study is at an early, exploratory stage and relies on limited information from secondary sources. Nevertheless, the results offer valuable insights into the ways governance modes and AI innovations are being applied in the water sector. By examining different

configurations of collaboration and government involvement in the Netherlands, Portugal and Poland, the study has begun to shed light on how various actors work together to foster innovation in the field. These initial results provide a strong starting point for a deeper understanding of the strategies and relationships that drive innovation, with a particular focus on environmental technologies to enhance sustainability. In analysing the cases, distinct patterns emerged:

1. In the Netherlands, a market-driven approach was identified, where the government engaged a private company, illustrating a commercial collaboration.
2. The Portuguese scenario revealed a blend of hierarchical and network modes, characterized by collaboration between water utilities and academic institutions, supported by a federal project.
3. The Polish case was predominantly hierarchical, featuring collaboration between federal and local water authorities.

Notably, despite the differences, governmental actors play a key and multifaceted role in all three cases, ranging from facilitators of the coordination to direct participants. A shared characteristic across the cases is a narrow innovation effort focused on environmental technologies to drive sustainability, with two of the three cases centring on wastewater treatment.

These results align with recent developments in governance research, particularly within the realm of meta-governance literature. Such literature recognises governmental actors as central policy coordinators via one or more governance modes (Gjaltema et al., 2020). Moreover, it emphasises the intricate coordination and collaboration with hybrid governance systems that comprise hierarchical, market, and network governance modes (Casiano Flores, 2022).

Considering this study's limitations, the next steps will involve conducting an in-depth and comparative analysis of the three cases and expanding the research to include other disruptive technologies from a governance perspective. This is needed to increase our understanding on the governance constrains and enablers of innovation within the water sector and for exploring the complex roles of digital public services users and providers in shaping water governance.

Understanding the limitations of this research, we propose as a next step to conduct in-depth case analysis including primary sources of data. We also invite future research to delve into and expand the understanding of the complex interplay between disruptive technologies, innovation, and governance in the water sector. Through in-depth and comparative studies, best practices and policies that facilitate the adoption of innovative and enhance water governance can be identified. This pursuit aligns with a broader objective of fostering a more sustainable and resilient water future.

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