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Economics of Hydraulics: Persian Qanats and Roman Aqueducts

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Abstract

This article examines how governance models shaped water management in ancient Persia, the Roman Empire, and medieval Europe, focusing on qanats and splendour fountains. It explores how each civilization's societal needs influenced their water infrastructure. The study highlights how environmental challenges led to adaptations in governance and engineering. These water systems were both functional and symbols of power. The research reveals the diverse approaches to water management across these cultures.

Keywords: Governance, Civil Architecture, Qanat, Splendour Fountain, Environmental Adaptation, Heritage.

JEL Classification Codes: N50, N90, Q25, Z13.

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Introduction :

Ancient water management systems not only showcase the technical capabilities of past civilizations but also reveal their governance models and fundamental interactions with nature. In contrast to other cultures that adapted their settlements to the available natural resources (Mays, 2010), the Persians and Romans transformed their environments to fulfill their needs. For instance, the underground city of Kish exemplifies a community-based, decentralized approach to aligning human settlements with natural resources (Figure 1), while the Cloaca Maxima in Rome represents a centralized effort to drain marshlands and facilitate urban expansion (Figure 2). While both systems share a similar approach, they reveal notable differences in governance: a community-based, decentralized management in the Persian qanats, especially in the Kurdistan region and the Persian Empire (Beaumont, 1989), and a centralized, hierarchical management in the Roman aqueducts and fountains (Hodge, 2002).

The central focus of this article is to understand how these hydraulic infrastructures reflect governance models, influenced by environmental pressures and economic demands. Persian qanats, managed by local communities (Beaumont, 1989), exemplify sustainability and communal cooperation, while Roman aqueducts and fountains represent political centralization, designed to showcase imperial power and meet urban needs (Hodge, 2002). These contrasts will be further explored in the Literature Review, where the evolution of these systems is examined within their economic and cultural contexts.

The article is based on the hypothesis that these infrastructures serve not only as technical solutions but also as reflections of governance structures and cultural worldviews. This hypothesis is explored in the Methodology section, which provides a comparative analysis of Persian qanat systems and Roman fountains, focusing on their design, functionality, and symbolic roles.

The objectives are threefold: (1) to examine how environmental constraints influenced governance models; (2) to compare the community-driven management of

Persian qanats with the centralized control of Roman aqueducts; and (3) to investigate the symbolic and identity-forming roles of these infrastructures. These aspects are explored in the Results section, where visual and functional comparisons highlight the contrasts between the two systems.

Finally, the Discussion section explores the implications of governance decisions in different environmental contexts and proposes directions for future research on the relationship between resource management and societal models. In conclusion, the article emphasizes how ancient hydraulic systems were not only responses to immediate needs but also embodied visions of human-nature relations that continue to inform current debates on sustainability.

Review of Literature :

Origins of water management: Iranian qanats and Roman aqueducts :

Ancient Water Management Systems in Arid and Semi-Arid Regions: The Iranian Qanat and Roman Aqueduct: Ancient water management systems in arid and semi-arid regions highlight two pioneering structures: the Iranian qanat and the Roman aqueduct.

1- The qanats: Developed by miners during the Achaemenid dynasty (around 558–330 BCE), employed underground channels to transport water to the surface through gravity flow. These systems were well-suited for regions like the Iranian plateau (Beaumont, 1989; Wulff, 1968). The distribution mechanisms (kesria) used in qanat systems demonstrated a form of collective, community-driven governance: these devices ensured the equitable distribution of water among users, thus guaranteeing a sustainable and fair access to this vital resource (Figure 3). According to Goblot (1979) and Boucharlat (2001), qanats were key innovations for both agriculture and domestic consumption, evolving to address the challenges of environmental water scarcity while sustaining human settlements. Arabic sources, such as the hydraulic engineering treatise by Al-Karaji, which was later translated into European languages, document these techniques and emphasize the extensive use of qanats across Persian territories, extending to the arid regions of North Africa and Central Asia.

2- The Roman aqueduct system : Developed in the Italian Peninsula, perfected Etruscan hydraulic technology through innovations such as elevated structures, arch-supported channels, and advanced siphons. Hodge (2002) and Aicher (1995) describe aqueducts as a response to the growing needs of urban populations, enabling the transport of water across diverse terrains. These infrastructures not only facilitated public access to water through monumental fountains and baths, symbolizing civic pride and political stability, but also played a crucial role in managing marshy lands and flood-prone coastal areas. In fact, drainage and diversion systems were often integrated into these infrastructures to maintain arable land and ensure urban sanitation in humid regions (Leveau, 1991; Evans, 1997). Furthermore, Arab historians, including Ibn Khaldun, demonstrate how Roman aqueducts in the territories they conquered impacted local water management practices and urban development, particularly in the Mediterranean and Central Europe.

Political and cultural dimensions of water systems :

The political structure of each empire shaped the design and symbolic use of water systems. The qanat system, often overseen by local councils, reflects the decentralized governance of the Persian Empire, encouraging communal water management (Wulff, 1968). Roman aqueducts, in contrast, acted as symbols of imperial authority. The Castellum Aquae, located at the final distribution point of the aqueducts, exemplified this centralization and underscored the state's ability to control and redistribute water to fulfill urban needs (Figure 4). According to Evans (1994) and Claridge (1998), these structures were frequently inscribed with the names of emperors or benefactors, reinforcing Roman power. Medieval Arab and Spanish sources suggest that aqueduct-inspired systems in medieval France and Germany adapted to local conditions but continued to serve as symbols of civic prosperity (Hansen, 2012).

Technological and Environmental Adaptations :

The environmental conditions of the Iranian plateau and Central Europe influenced the engineering priorities of each water system. Roman aqueducts relied on

visible, elevated structures to traverse diverse landscapes and transport surface water (Aicher, 1995), while qanats operated underground, shielding the water from evaporation in arid climates (Beaumont, 1989). Figure (5) depicts the Niavaran Qanat, which represents a community-driven approach to water management in arid regions, where every technical aspect is designed to minimize resource loss. In contrast, Figure (6) features the Fountain of Augustus in Augsburg, a symbol of imperial power and centralization, where water serves both a practical and symbolic role in an urban setting. These differences emphasize the technical sophistication needed to tackle the specific challenges of each region. The historical review of these water systems highlights how environmental factors, political priorities, and cultural values shaped water management practices in ancient empires. This section aims to establish a framework for analyzing the evolution of water systems in relation to their lasting social, economic, and symbolic roles.

Existing comparative studies on water management systems :

Comparative studies on ancient water systems often emphasize the technological differences between Persian qanats and Roman aqueducts. However, few studies investigate how political dynamics and community governance shaped the development, use, and symbolic significance of each system, especially regarding community-based management versus centralized administration.

Political and communal management :

Beckers and Berking (2019) examine the socio-political aspects of water management in Persia and the Roman Empire, emphasizing how the communal nature of qanats reflects local governance. Their study contrasts the decentralized, democratic management of qanats with the centralized administration of Roman aqueducts. However, although the study provides valuable insights into governance structures, it lacks a comparative analysis of how these political differences influenced the social and symbolic roles of the systems.

Shared Management Practices :

Goblot (1979) provides an in-depth analysis of qanat structures and compares their decentralized management with similar practices observed in the Mediterranean. He briefly mentions water management practices in Southern Europe, particularly in Spain, where systems like the Cortes de Agua reflect an indirect influence of Persian qanats, passed down through Arab domination. These water tribunals, representing shared governance, demonstrate how community-based management principles, inherited from the qanats and adapted by the Arabs, shaped the organization of water distribution and usage in Spain. This example provides an interesting contrast to the Roman model, which was more centralized, while also shedding light on the cultural transmission of water management practices.

Technological and symbolic comparisons:

Hodge (2002) examines Roman aqueducts in terms of their scale, construction, and centralized administration, contrasting them with the resource-efficient qanats. While he highlights technical differences, his study does not address how the governance model of each system influenced its symbolic significance. Figure (7) depicts the distribution ''combs'' (kesria) of a qanat, which allocate water equitably among users in a decentralized, communal spirit. In contrast, Figure (8) shows the Roman Castellum Aquae, a centralized water management structure that reflects state hierarchy and pre In Spain, water tribunals like the Cortes de Agua offered a well-established, participatory model of community-based water management, which could further highlight the role of shared governance in public access to water and decision-making.

Cultural and Symbolic Contexts :

Claridge (1998) explores the Roman use of water for monumental public fountains, which symbolized civic pride and imperial power. While Roman aqueducts were overseen by appointed officials, local communities managed qanats democratically, reflecting a distinctly Persian approach to collective resource management. Claridge's study emphasizes the civic role of Roman aqueducts but does

not examine how the symbolic, community-based management of qanats could represent an alternative collective model of power and control over water resources.

Overall, while these studies offer valuable insights into the technical and administrative characteristics of qanats and aqueducts, a deeper analysis of democratic water governance, particularly in Persian qanats and systems like the Cortes de Agua in Spain, could shed light on how political dynamics influenced the social and symbolic roles of these ancient water systems. This article builds upon these studies by examining the connection between political practice, collective water management, and the broader social symbolism of water in ancient communities

Methodology:

This article employs a comparative content analysis of historical sources to investigate how governance influenced the engineering and symbolism of wells- ranging from simple utilitarian structures to elaborate public fountains- in ancient Persia, the Roman Empire, and medieval Spain. The study also explores the impact of climate and economic needs on governance decisions, while proposing potential avenues for future research.

1. Selection of cases and sources for analysis :

The article focuses on three distinct water management systems, each defined by specific governance models, economic functions, and unique architectural features:

Persian qanats :

Underground channels that provide sustainable water distribution in arid regions, managed communally and particularly suited for agricultural use. Key architectural features include ventilation shafts to maintain water flow and reduce evaporation, as well as cooling chambers that utilize the cool air from the qanats for storage and climate control (Goblot, 1979; Beaumont, 1989). This system highlights sustainable, community-driven management, focusing on practicality rather than decoration.

Roman aqueducts and public wells:

Elevated structures designed to ensure urban hygiene and separate industrial water from civic water. Architectural elements include arches for spanning valleys, sedimentation basins for filtration, and public fountains symbolizing civic pride and political power (Hodge, 2002; Aicher, 1995). Managed centrally by appointed officials, Roman aqueducts played both functional and symbolic roles, reflecting the state's commitment and dedication to public health and civic life.

Spanish community water systems :

Water governance in medieval Spain involved systems managed by both the community and local authorities, such as the Tribunal de las Aguas de Valencia and the Irrigation Communities, which were particularly effective in agricultural regions. Architectural features included practical canal networks (acequias) for fair distribution, reflecting governance tailored to regional needs (Maass & Anderson, 1978; Peris & Martínez, 2013).

Primary sources include translated historical texts, legal documents, and inscriptions, while secondary sources offer analyses of governance structures, architectural design, and the social roles of each system.

2. Thematic Analysis :

The thematic analysis explores two key areas to understand the impact of governance on the engineering, functionality, and symbolism of water systems, with a brief consideration of the potential influences of economy and climate:

Governance and management structures :

This theme evaluates the community-based management of Persian qanats, the hybrid governance in Spanish systems (involving both community representatives and local authorities), and the centralized Roman model. Governance choices are analyzed to demonstrate how they shaped the architecture and function of water systems, from the utilitarian qanats in arid regions to Roman aqueducts that served both sanitation and civic pride. The Spanish example highlights how governance adapted to regional

climate and economic needs, with community governance often being more prominent in arid agricultural areas (Beckers & Berking, 2019; Wilson, 2008).

Symbolism, Hygiene, and Civic Identity :

This theme explores the social and symbolic roles of water systems—whether they function solely as practical resources or as emblems of civic pride and political authority. Persian and Spanish systems were typically modest and focused on community use, while Roman aqueducts and fountains symbolized the power of the state and efforts toward public health (Evans, 1994; Claridge, 1998). The Spanish model also demonstrates how shared governance in arid regions led to the creation of functional and modest irrigation structures, while certain urban areas under local administration incorporated civic water features (Maass & Anderson, 1978).

3. Comparative Synthesis :

This analysis aims to clarify how governance has influenced the symbolic and functional roles of water systems, shaped by economic practices and climatic needs. Community-based governance systems, such as the Persian qanats and the Spanish water courts, typically led to practical and sustainable structures. In contrast, Roman centralized systems allowed for the grandeur of public fountains, supporting urban hygiene while symbolizing the power of the state. The hybrid model of medieval Spain, which combined local authorities and community governance, illustrates how adaptive governance shaped hydraulic infrastructures that balanced both practicality and civic expression.

Through this comparative framework, the article suggests that climate, economic demands, and governance collectively influenced water management systems in antiquity, providing a foundation for future research on the interaction between these factors.

Results :

This article contrasts the architectural and socio-economic principles embedded in two distinct water management systems: the democratic Kariz (qanat) system of pre-

Islamic Western Asia and the grandeur fountains of hierarchical Roman and later European traditions. While the Kariz prioritizes community access and the fair distribution of resources, the grandeur fountains symbolize the concentration of power and wealth through ornamental structures in public spaces. The inclusion of diagrams, photographs, and historical engravings in this section enriches the visualization of these philosophies, offering insights into how economic systems and social hierarchies are materially reflected in water management infrastructure.

Kariz Systems: Community and Sustainability :

The Kariz system, or qanat, originating in ancient Kurdistan, represents a community-centered approach to water management, focusing on sustainable access and the fair distribution of resources. These underground channels harness groundwater and deliver it to villages, ensuring consistent irrigation for crops and reliable access to drinking water. The practical, unadorned design of the Kariz reflects its social intent: to serve communities rather than to impress or assert power.

A structural diagram of a Kariz system (see Figure 3) demonstrates how these underground channels effectively deliver water directly to agricultural fields, with minimal evaporation losses (Lightfoot, 1996). This understated, subterranean design stands in stark contrast to European traditions, which prioritize visually dominant above-ground structures. Furthermore, photographs of the Kariz wells at Niavaran (see Figure 1) highlight the lack of ornamental features, emphasizing the community values of resource sharing and access that are central to the philosophy of the Kariz (Goblot, 1979).

Fountains of grandeur: Hierarchical display and symbolic power

In contrast, the grandeur fountains of the Roman and later European periods represent a hierarchical approach to water management. These fountains, often situated in prominent urban locations, employed elaborate designs to symbolize wealth and authority. Engravings of Roman fountains, such as those discovered in Pompeii,

illustrate how water elements were crafted as civic symbols, with ornate stones and central placement in public forums to signify state power (Hodge, 2002).

A photograph comparing a Renaissance fountain in Italy with a qanat outlet in Iran (see Figures 1 and 2) further highlights these differences. While the Kariz is purposefully modest and functional, grandeur fountains are designed to impress and assert authority through their monumental scale and ornamental details. These architectural choices reflect the socio-economic systems in place: Kariz systems represent community-based resource sharing, while grandeur fountains symbolize hierarchical control, often financed by wealthy patrons or governing institutions as a demonstration of their status (Chilton, 2019).

Visual Comparisons :

To support these conclusions, visual comparisons are crucial for illustrating the contrasting philosophies behind the Kariz systems and grandeur fountains. Figures 1 to 4 include, respectively, a photograph of a qanat outlet, a structural diagram of a Kariz, a Renaissance fountain in Germany, and a Roman aqueduct in France. These images provide an opportunity to juxtapose the functional and egalitarian design of the Kariz with the grandeur of European fountains, demonstrating how each system reflects its underlying social values (Lightfoot, 1996; Goblot, 1979).

Other historical engravings of Western European cities depict fountains in central squares, embellished with statues and flowing basins, with each detail emphasizing the socio-political significance of public display. Unlike the Kariz, these fountains are mainly decorative and centralized, serving as symbols of political power rather than practical means of water distribution (Hodge, 2002; Chilton, 2019).

Discussion :

This article has highlighted the complex relationship between climate, economic needs, and governance in shaping water management systems across various cultural and environmental contexts. For instance, in arid regions such as Sfax, traditional rainwater harvesting practices, as illustrated in Figure (9), reflect a community-based

management approach aimed at optimizing limited resources. These techniques contrast with systems like that of Augsburg, depicted in Figure (10), where Roman influence led to a strict separation between drinking water and utility water, demonstrating a more centralized and organized approach.

These examples demonstrate how societies have adapted their water management systems to their specific environments, incorporating social, economic, and cultural considerations. They also highlight how these systems reflected governance philosophies, ranging from community-based management to more hierarchical and centralized approaches.

Water governance and management: Climatic and economic influences :

The climate and economic demands of a region are critical factors in determining its water governance and management model. In the arid climate of the Iranian plateau, water scarcity required a community-oriented governance approach, promoting local collaboration to maintain agricultural productivity. Through a system of shared management, qanats provided communities with access to limited water resources and facilitated their efficient distribution, fostering collective responsibility and emphasizing the notion of water as a shared resource vital for survival (Lightfoot, 1996; Goblot, 1979). These practices highlight a governance model centered on resource sharing to ensure sustainable agriculture.

By contrast, the more temperate climate of the Roman Empire introduced different challenges. The wetter soils and construction obstacles required a specialized approach, prioritizing urban infrastructure adapted to these conditions, such as aqueducts and public fountains, which served both functional and symbolic roles. These structures met public health requirements and ensured the separation of industrial water uses while asserting centralized authority through monumental architecture that celebrated civic identity (Chilton, 2019; Hodge, 2002). The grandeur of these fountains symbolized the state's power and its dedication to public well-being, enhancing urban sanitation and supporting densely populated areas. This focus on adapting to local climatic conditions

and economic needs highlights the influence of these factors on governance models and water management practices, tailored to the unique requirements of each society.

Future research directions: Governance, environment, and economic needs :

The conclusions of this article suggest several directions for future research. First, further exploration of how governance models are adapted to meet specific economic needs, such as agriculture in arid climates or urban sanitation in more temperate regions, could provide valuable insights into the interaction between environmental constraints and societal demands. This approach would involve examining regional variations within each governance model to uncover local responses to resource scarcity or abundance. For instance, investigating the differences in qanat governance across arid regions could offer perspectives on community-driven adaptations, while studying Roman hydraulic infrastructure across diverse climates could reveal public health priorities.

Furthermore, further research could explore how governance structures have evolved in response to changing environmental and economic conditions, such as population growth, climate variability, and economic shifts. By examining how governance models have adapted to these pressures, researchers can better understand how societies have historically balanced environmental constraints with economic needs. Analyzing these factors in various contexts would deepen our understanding of the broader interplay between climate, economic demands, and governance evolution, providing valuable insights into how societies address current environmental challenges.

Conclusion :

In conclusion, this comparative content analysis of qanat systems in Western Asia and Roman-European splendor fountains underscores the profound influence of environmental and economic contexts on governance models and water management practices in different societies. The community-based governance of qanats on the Iranian plateau, shaped by arid conditions, promoted a resource-sharing model crucial for agricultural sustainability. This system fostered local collaboration and collective

responsibility, embedding water management within the community as an essential element for survival. In contrast, the Roman Empire's approach to water management, facilitated by a more temperate climate, prioritized the development of urban infrastructure and public health. Roman aqueducts and grand fountains not only served practical purposes for urban hygiene and industrial separation but also symbolized the commitment of a centralized authority to public welfare, strengthening and reinforcing civic pride and state identity.

The analysis demonstrates that governance systems and infrastructure are closely linked to environmental conditions and economic demands. In resource-limited regions, such as the Iranian plateau, community-based governance models developed to address these challenges effectively. In more resource-abundant and temperate regions, like those under Roman control, centralized water management prioritized urban sanitation and public health, reinforcing a different societal structure.

These findings suggest that climate and resource availability not only determine survival strategies but actively shape societal structures and governance philosophies. Future research could build on these studies by exploring how governance models evolved in response to changing environmental and economic pressures over time, offering valuable insights into the historical adaptability of societies to resource constraints. This exploration deepens our understanding of historical water management, both as a practical and symbolic aspect of governance, providing a perspective to address modern challenges of resource sustainability and climate adaptation.

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Appendices:

Table No. (1): Visual comparison of ancient hydraulic systems

	
Figure 1: Blondinrikard Fröberg. (2015, December 26). Underground city (Kish) [Photograph]. CC BY	**Figure 2**: Lalupa. (2005, December 11). 040227 tevere16CloacaMaxima [Photograph]. Public

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	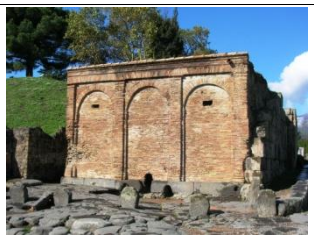
Figure 3: Taguelmoust. (2005, May 26). Foggara 02 [Photograph]. CC BY-SA 3.0. Wikimedia Commons.	**Figure 4**: Mentnafunangann. (2012, November 7). Castellum Aquae 1 [Photograph]. CC BY-SA 3.0. Wikimedia Commons.
	
Figure 5: Qanat Niavaran, a symbol of community resource management. Zereshk. (2005, December 16). Qanat Niavaran [Photograph]. Wikimedia Commons. CC BY-SA 3.0.	**Figure 6**: Augustus Fountain in Augsburg, representing imperial authority. Reinhardhauke. (2006). Augsburg Augustusbrunnen 4 [Photograph]. Wikimedia Commons. CC BY-SA 3.0.
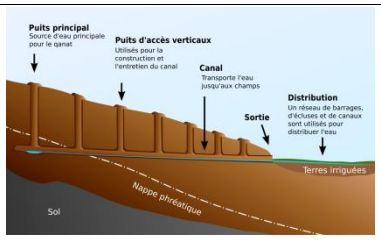	
Figure 7: Diagram of a qanat showing the underground structure designed for community water management. Samuel Bailey, translated into French by Skime. (2019, March 13). Diagram of a qanat [Diagram]. Wikimedia Commons. CC BY-SA 3.0.	**Figure 8**: View of the Pont du Gard aqueduct, illustrating its dual use for water transport and passage of vehicles and pedestrians. Wieschendahl, G. (2004, June 6). Pont du Gard [Photograph]. CC BY-SA 3.0.
	
Image 9: Vanderbilt, W. K. (1918, January 1). At Sfax, showing how the rainwater was gathered [Photograph]. Public domain. The Library of Congress: https://lccn.loc.gov/18012078.	**Image 10**: Mailtosap. (2019, June 25). Siebenbrunner Bach Augsburg Kreuzung 3 [Photograph]. CC BY-SA 4.0. Wikimedia Commons.