

Sustainable Approaches in Water Tariff Design to Reduce Water Service Divide

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Abstract. Inequality in access to water and the use of the water service is a global problem which requires an equitable distribution of the resource and its efficient management. Although universally recognized by the United Nations as an inviolable human right, access to water and sanitation is often characterized by inequalities which also manifest themselves through different levels of quality in the provision of water supply, purification and sewer.

Also in Italy, the Water Service Divide is significant and affects about a third of the population. The National Regulatory Authority for Energy, Networks and the Environment (ARERA) has introduced a simplified approach to defining water tariffs aimed at water operators with difficulty overcoming this problem. However, the scheme is not always easily applicable, especially in cases where it is also necessary to design the tariff structure and the related incremental blocks (or brackets). To remedy this criticality, in the present work a mathematical programming model is proposed, based on the simplex algorithm, which allows the estimation of water tariffs and consumption blocks also for water operators characterized by the absence of data on costs and revenues of water management. The proposed model, which guarantees compliance with all the economic constraints imposed by the national Authority, makes it possible to design consistent tariffs between the various water service operators, reducing management gaps. The model, easily applicable by the operators, can also represent a simplified scheme for the initial tariff planning which is independent of the knowledge of the data on operating costs and revenues.

Keywords: Water Service Divide · Water inequality · Water Tariff · Simplex Algorithm · Water Economics · Economic Evaluation of Projects

1 Introduction

Water is a fundamental resource for life and the development of human activities. Due to its use in multiple fields (mining, energy, agriculture, industry, domestic, etc.), water often becomes the object of conflict and different interests in terms of management and use. Because of this, situations of water inequality, unfortunately, occur, i.e. unequal distribution and scarce availability of the resource in some areas of the planet. Population

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growth, the climate crisis, consumerism and the expansion of markets have strongly contributed to the increase in water consumption, putting the poorest populations in a condition of scarcity above all and expanding the phenomenon of the Water Service Divide [1].

By Water Service Divide we mean the disparity in access to water resources by users, which manifests itself through different levels of quality guaranteed in the provision of the aqueduct, sewerage and purification services. In this regard, substantial imbalances regarding access to water resources and the methods of managing water services exist. This translates into the so-called "citizenship gap", i.e. an asymmetry in the delivery methods of services offered at a territorial or national level [2]. This water inequality, which implies a non-optimal and homogeneous resource allocation, is often caused by obsolete management methods that generate impartiality and further amplify social stratification [3, 4]. While on the one hand water and sanitation have been universally recognized by the United Nations as an inviolable human right (as enshrined in the Sustainable Development Goal 6—SDG6—of the 2030 Agency), On the other hand, huge challenges lie ahead in curbing the water inequality and ensuring effective safe access to water resources for all people [5]. In this sense, many studies have recently been conducted aimed at measuring inequality in access to water, even if specific and unambiguous metrics to be adopted to achieve the SDG6 sustainable development objective have not yet been identified [6]. Furthermore, this goal is still difficult to achieve, since about one in ten inhabitants of the planet still does not have safe access to water. It is estimated that 80% of people without access to safe drinking water live in rural areas. Serious inequalities are also recorded regarding access to sanitation. Only 55% of the world population lives in conditions of hygienic-sanitary security. Continuing with current consumption patterns, it is estimated that by 2025 around two-thirds of the planet's inhabitants will live in countries characterized by water stress [7]. Currently, North Africa, East Africa, Southern Africa, the Middle East, China, Mexico and India are the most water-poor countries in the world. Around 2 billion people for whom water stress is a serious problem are concentrated in these areas. Among the areas richest in water, we find South America, Oceania, Northern Asia and North America (in particular Canada, with a per capita availability of water ranging from 10,000 to 50,000 L per person). In Europe, there are inequalities between the northern and central-southern territories. Water availability varies between an average of 65,000 L for Great Britain, France, Italy, Spain, Portugal and Greece and an average of 5,000 L for Germany, Poland and Romania. In the Mediterranean basin, Italy is the richest country in water resources thanks to the presence of the Alps. However, there are important inequalities between the North and South [8]. According to ISTAT statistics for the years 2015–2018, Italy is in first place in the EU for withdrawals of water for drinking use: 428 L per inhabitant per day. However, just under half of the volume of water withdrawn from the source (47.9%) does not reach the end users due to water losses from supply and distribution networks. The daily supply for potable use is quantifiable in 220 L per inhabitant. 21.3% of families connected to the municipal water network consider themselves very satisfied with the service offered, while 63.3% are quite satisfied. The overall level of satisfaction varies significantly in the area. Very or fairly satisfied families are nine out of ten in the North, eight in the Center and in the South and down to seven in the Islands. The share

of families who prefer not to consume tap water is still significant, despite the degree of trust showing a progressive improvement: from 40.1% in 2002 to 29.0% in 2018, for a total number of families equal to 7 million 500 thousand.

As regards the issue of the Water Service Divide in Italy, the most recent studies show that the infrastructural gap between the North and the South of the country is significant. In particular, in the face of a large area of the country, located mainly in the North and in the Center, in which the use of services, the implementation of investments, the regional legislative activity, the decision-making mechanisms of the government bodies of the field and the managerial and industrial capabilities of the operators appear to be in line with the achievement of the highest objectives in the sector, situations persist, mainly in the South and in the Islands, in which there are inefficiencies [9].

In fact, in the South water service providers are often subsidized by public institutions to mitigate the infrastructural gap with the North of the country and to improve the quality standards in the supply of the resource [10]. This gap is due both to the inefficiency of the distribution network since in some provinces of the South and Islands water losses exceed 50% [11], and to the inability of low-budget business management to ensure industrial management of the service, with the emergence of economies of scale that allow for compliance with the Italian and European principle regarding full cost recovery. Economies of scale and scope are pursued through the push towards the definition of supply basins of at least provincial size, as well as through the vertical integration of the water service, which provides for management by a single assignee of the aqueduct, sewerage and purification activities [12].

In Italy, today, there are over 8 million inhabitants of self-managed municipalities; of these, about 65% are in the south of the country.

To promote increasing levels of provision of water services in disadvantaged areas and to level the inequalities in terms of accessibility to water between areas of the country, the Regulatory Authority for Energy, Networks and Environment (ARERA), an Italian body that carries out regulation and control activities in various sectors, including the water sector, has promoted simplified forms of tariff regulation. The main objective is to strengthen the aggregation processes between the managements, highly fragmented throughout the country, and to overcome the Water Service Divide. To this end, with Resolution 580/2019/R/idr (Approval of the Water Tariff Method for the third regulatory period MTI–3), ARERA introduced the Convergence Regulatory Scheme to which those managements that have persistent levels of criticality in carrying out the planning and implementation of infrastructural interventions. The Convergence Regulatory Scheme introduces important simplifications that allow water tariffs to be determined on a parametric basis in the absence of significant technical and/or economic data [13]. In analogy to what is envisaged for managing entities in an ordinary state of operation (i.e. which do not present deficiencies in terms of technical-economic data), a structure of the respective for Increasing Block Tariffs (IBTs) [14]. This method of tariff articulation provides for the planning of water tariffs which progressively increase as consumption increases. Each tariff is made up of a fixed portion and a variable portion. The fixed portion is aimed at covering the fixed costs of supplying the service, while the variable portion has the objective of promoting sustainable use of water by associating progressively higher tariffs with increasing blocks of consumption. The IBT structure intends

to reward the most virtuous users and, at the same time, penalize those who consume greater volumes of water [15]. In summary, the Convergence Regulatory Scheme allows for the definition of the water tariff for each consumption block for water operators for which deficiencies emerge in the deeds and data necessary for tariff purposes. In other words, the Convergence Regulatory Scheme allows operators with difficulty to plan the gradual achievement of specific regulatory objectives over four years. Nonetheless, the scheme in question does not eliminate some critical issues. In particular, in the case of total absence of tariff, cost and consumption data, a recurring situation for low-budget business management, it is difficult to estimate the tariffs and define the consumption blocks for those operators characterized, in fact, by persistent criticalities.

To make up for the structural gaps inherent in the Convergence Regulatory Scheme, this work proposes a mathematical programming model, based on the simplex algorithm, which allows the definition of water tariffs and consumption blocks also for those less virtuous companies that do not have enough data on tariffs, costs and volumes of water consumed. The model can guarantee compliance with all economic constraints imposed by the National Authority (ARERA). The ultimate goal is to level out inequalities in terms of accessibility to water and to align the less virtuous operators with the more efficient ones.

The work has the following structure: Sect. 2 is dedicated to the analysis of the reference literature; Sect. 3 describes the regulatory constraints established by ARERA; Sect. 4 presents the proposed model; Sect. 5 shows the main conclusions highlighting future research ideas.

2 State of Art

One of the most used methods to solve problems related to the management of water resources consists of the modelling and simulation of water systems [16]. For example, through simulation scenarios in the management of water resources, it is possible to identify water pricing and market mechanisms, i.e., policies and strategies that envisage the use of economic incentives to manage water demand and allocate water resources more efficiently. The water pricing approach is to set rates that reflect the true cost of water, including the costs of supply, treatment and distribution. This can incentivize users to save water and use it more efficiently. In some cases, water pricing can also be used to generate revenue to support water infrastructure and conservation efforts. The market-based approach is the creation of water markets, where water rights can be bought and sold and water can be allocated based on market demand. The market-based approach can help allocate water resources more efficiently and provide opportunities for water users to trade the resource, ensuring that water is distributed where it is most valued.

Another useful method in solving issues related to the planning and management of water resources is the application of optimization techniques. Over the years numerous studies have been conducted aimed at the conservation and correct allocation of water resources through optimization tools [17]. Indeed, optimization methods can be used to determine the best allocation of water resources in a complex water system. This can help ensure that water resources are used efficiently and sustainably. For example,

Yang et al. (2012) apply a decentralized optimization method to solve a water allocation problem in the context of a river basin [18]. Second, optimization methods can be used to plan long-term water resources management, taking into account different future scenarios. This can help identify the most effective management options to ensure the long-term availability of safe drinking water. For example, Maiolo et al. (2017) devised a model for optimizing drinking water distribution systems to the effects of climate change [19]. Finally, optimization methods can be used to determine optimal water rates that reflect the true cost of water. This can incentivize users to save water and use it more efficiently. To cite one example, Pulido-Velazquez et al. (2013) present a method for simulating water pricing policies related to resource availability and for designing efficient pricing policies that incorporate the marginal value of water. They then followed two approaches: priority-based simulation and economic optimization [20]. In another work, Abdulbaki et al. (2017) present an integer linear programming model for the optimal treatment and allocation of water resources. The model seeks to minimize the total cost of water, including the economic cost of treatment and distribution, as well as associated environmental costs [21]. Macchiaroli et al. (2023), propose an optimization model aimed at designing sustainable water tariffs for users and, at the same time, able to discourage excessive water consumption [22].

Also in the present work, a mathematical optimization model is used. In particular, the simplex algorithm is applied to design the water tariffs and to define the consumption blocks in compliance with the constraints envisaged in the Convergence Regulatory Scheme. The simplex algorithm is a linear programming (PL) method used in operations research to find solutions to an optimization problem. It was conceived by George Dantzig in 1947 [23]. It is often the most efficient algorithm for solving linear programming (LP) problems [24]. The simplex algorithm is an iterative optimization method used to solve linear programming problems. In particular, the simplex algorithm is used to find the maximum or minimum point of a linear function subject to linear constraints. This algorithm is based on the idea of moving along the boundary of the feasible domain of a linear programming problem until reaching the maximum or minimum point. The feasible domain is the set of all possible solutions that satisfy the linear constraints of the problem. The simplex algorithm starts with a feasible solution to the linear programming problem. This solution can be determined for example by using the Gauss elimination method to solve the system of linear equations associated with the problem. Next, the algorithm tries to improve the solution iteratively. At each iteration, the algorithm selects a basic variable and a non-basic variable and calculates the ratio of the objective function value to the coefficient of the basic variable in the corresponding row of the constraint matrix. The selected basic variable is then swapped with the non-basic variable, thus changing the solution to the problem. This process is repeated iteratively until the maximum or minimum point of the objective function is reached [25–27]. The simplex algorithm has been used in some studies for planning water resource management systems [28–30]. But there are no significant examples of application cases aimed at designing water tariffs in compliance with regulatory constraints.

The following section describes the proposed model starting from the definition of the basic economic constraints introduced for those operators that must refer to the Convergence Regulatory Scheme.

3 The Design of the Water Tariff

In Italy, ARERA, for each regulatory period, defines the cost component and updates the tariff method starting from regulatory schemes. During the last period the national Authority had to integrate the methodology for the recognition of electricity costs to protect the economic sustainability of service operators due to the particular volatility of energy prices [31–34].

The Resolution n. 580/2019/R/idr (Water Tariff Method for the third regulatory period MTI-3) introduces the new provisions concerning the determination of tariffs for the performance of aqueduct, sewerage and purification services for the years 2020–2023. Through the application of regulatory schemes, it is possible to define, for each management, the value of the tariff multiplier ϑ, i.e., the coefficient by which to multiply the tariffs in force to update them to the expected costs and revenues.

The applicable tariff rules are attributable to two schemes: (i) the Regulatory Schemes Matrix, where the operators in possession of all the required technical and economic data can select the most appropriate operating scheme based on the starting conditions of the management; (ii) the Convergence Regulatory Scheme that presents simplified rules for management where there is a lack of data necessary for the preparation of water tariffs.

The Convergence Regulatory Scheme applies to management companies with persistent criticalities in the performance of service planning activities, and investment implementation and which have conditions of exclusion. In the case of the convergence scheme, the cost items to be recognized in the tariff are parametrically reconstructed based on reference benchmarks. The simplified rules are applicable only for the current regulatory period, at the end of which the management must refer to the ordinary Regulatory Schemes Matrix.

The Convergence Regulatory Scheme shall apply to those operations covered by one more of the following cases:

1. Tariff revenues, costs and management quality data are known;
2. Only tariff revenues are known;
3. Neither tariff revenues nor operating costs are known.

In the first two cases, the tariff multiplier, for each a = {2020, 2021, 2022, 2023}, is calculated as follows:

$$\vartheta^a = (1+\alpha Y), \tag{1}$$

where (α) is the *aggregation factor*, equal to 1.5 for those managements that have started an aggregation process and equal to 1 in the absence of this process. The parameter (Y) is instead the *increment factor*, which represents the ability over time of the operator to adapt to current regulatory provisions. In particular, it is equal to 5% for the first year, 4% for the second, 3% for the third and 2% for the last year.

In the absence of both revenue and cost data, the tariff multiplier is a function of the Operator's Revenue Constraint (VRG), i.e. the maximum value of revenues that can normally be obtained from management, as established for ordinary operators that refer to the Regulatory Schemes Matrix.

However, in the case of the Convergence Regulatory Scheme, this constraint is calculated in a simplified manner, taking into account only two cost items estimated on a parametric basis. In particular, we have:

$$VRG^{a}_{conv} = \left(Capex^{a}_{conv} + CO^{S}_{conv}\right), \tag{2}$$

where VRG^{a}_{conv} is the Operator's Revenue Constraint who does not have the revenue and cost data, $Capex^{a}_{conv}$ is the cost of capital set equal to $16\% \cdot CO^{S}_{conv}$, and CO^{S}_{conv} are the operating costs also estimated on a parametric basis, following the provisions of art. 17 of Resolution 580/2019/R/idr, to which appropriate simplifications are applied, not illustrated here for obvious reasons of synthesis.

The Area Governing Body (EGA), to which the management for which the convergence regulatory scheme is applicable, refers is required to fulfil a series of obligations for each of the years of the regulatory period. In particular, the obligations to be fulfilled within the first year are as follows: to carry out the recognition of the level of availability and reliability of technical data, to assess whether the water distributed to users complies with the Quality-of-Service Regulation (RQTI), to adopt a program for achieving compliance with the Urban Waste Water Management (RQTI) legislation. The obligations of the second year consist in certifying the correct preparation of the technical-accounting registers and defining the structure of the fees for each service. For the third year, the EGA must verify whether the operator has fulfilled the contractual quality data reporting and recording obligations under the standard (RQSII). Finally, for the fourth year, monitoring obligations, the preparation of registers, and the communication of technical quality data must be attested and the reliability of measurement data must be verified [13].

From the obligations of the EGA, it emerges that the structure of the fees for water services must be defined within the second year of the regulatory period, following the indications of Annex A of Resolution 580/2019/R/idr (Integrated Text for Water Services Tariffs - TICSI).

The proposed work focuses precisely on the structure of water tariffs, in particular for domestic users; domestic use accounts for about 73% of the total volume of water supplied annually on the national territory [35]. In this regard, the National Authority in the TICSI defines a structure that contemplates a fixed tariff portion, not correlated to consumption, and a variable tariff portion, proportionate to consumption and variable by consumption range. The latter portion is determined once the consumption ranges have been established using the standard per-capita criterion, i.e. considering a typical domestic user made up of three people. In the articulation of the ranges, again the ARERA regulation provides for a consumption range at a reduced tariff (T_{red}), a range at a basic tariff (T_{bas}), and excess ranges which can vary from 1 to 3 (T_{exc1}, T_{exc2}, T_{exc3}). If the adoption of the standard pro-capita criterion is used, for each domestic user, the subsidized consumption range corresponds to the interval between 0.00 m^3/year and 55.00 m^3/year (minimum quantity of water to be guaranteed for a user made up of three people). T_{bas} is stable by updating the basic tariff previously in force using the multiplier ϑ, T_{red} must be between 50% and 80% of T_{bas} (in this regard, it is the EGA that imposes the percentage value to be adopted on the low-budget business management), the maximum overage fee must be less than or equal to six times T_{red}. Also, the overage

tariffs must be incremental to each other. The fixed tariff portion must not exceed 20% of the total revenues obtainable from the aqueduct service. Finally, the TICSI requires that the following constraint be respected (iso-revenue):

$$\sum_u tarif_u^a \cdot \left(vs_u^{a-2}\right)^T = \sum_u tarif_u^{new,a} \cdot \left(vs_u^{new,a-2}\right)^T, \quad (3)$$

where $\sum_u tarif_u^a \cdot \left(vs_u^{\text{a-2}}\right)^T$ are the revenues derived from pre − existing articulations, while $\sum_u tarif_u^{new,\,a} \cdot \left(vs_u^{new,a-2}\right)^T$ are the revenues obtainable by applying the new tariff structure to the new reclassification of volumes consumed (or scale variables, vs) defined according to the TICSI criteria [36].

However, the application of TICSI in the case of operators that refer to the Convergence Regulatory Scheme appears critical for the aspects illustrated below. This occurs above all for case 3, i.e. when the operator has neither the tariff data nor the cost data. As is often found, these operators do not even have suitable data measuring the actual consumption of each user, or in any case, the information kit is incomplete and fragmented. It, therefore, becomes complicated to use both the per capita criterion based on actual consumption and the standard type to establish consumption ranges. Therefore, it is not possible to define in Eq. (3) the values of vs_u^{a-2} and $vs_u^{new,a-2}$, condition essential to comply with the iso-cable constraint imposed by the Authority.

To find a solution to the problem, further simplifying hypotheses are introduced in the next paragraph and a mathematical programming model is proposed which makes it possible to define the tariffs to be applied to each consumption class, also for those managements which use the Convergence mechanism in the total absence of data.

4 The Proposed Model

In applying TICSII to operators that use the Convergence Regulatory Scheme, the following water tariff ranges were considered (Table 1):

Table 1. Minimum tariff ranges for the aqueduct service.

Tariffs	Consumption ranges	
	Min (m^3/year)	Min (m^3/year)
T_{red}	0	55
T_{bas}	56	220
T_{exc}	>220	

The definition of the size of the three consumption classes and the use of a single excess tariff derives from the observation from the national average data to municipal management in economics [35].

In the absence of information on previous revenues and consumption for each user, the proposed model opts for the replacement of the first member of (3) with the Operator's

Revenue Constraint as defined in the case of convergence through Eq. (2). In this way, we obtain the following equation of the iso-revenue:

$$VRG_{conv}^{a} = \sum_{u} tarif_{u}^{new,a} \cdot \left(vs_{u}^{new,a-2}\right)^{T}. \tag{4}$$

The second member of (4) is equal to:

$$\sum_{u} tarif_{u}^{new,a} \cdot \left(vs_{u}^{new,a-2}\right)^{T} = \sum_{u} T_{RES}^{new,a}, \tag{5}$$

where $T_{RES}^{new,a}$ is the fee for the aqueduct service for a resident user, equal to:

$$T_{RES}^{new,a} = {QF_{ACQ}}^{new,a} + {T_{red}}^{new,a} q_{red} + {T_{bas}}^{new,a}(q_{bas}) + {T_{exc}}^{new,a}(q_{exc}). \tag{6}$$

where $QF_{ACQ}^{new,a}$ is the fixed tariff portion of the aqueduct service and the components q represent the volumes annually consumed by a user in a year, divided by the respective consumption ranges. In the case in question, in the absence of data on annual consumption volumes per user due to management criticalities, a distribution of volumes in tariff ranges derived from national data is considered [35]; in particular, the tariff relating to the first range (T_{red}) is applied to 34% of resident domestic consumption, the tariff relating to the second range (T_{bas}) is applied to 60% of consumption, and the tariff relating to the third range (T_{exc}) is applied to 6% of consumption.

Having defined the multiplier ϑ with the convergence scheme, the T_{bas} is known. $QF_{ACQ}^{new,a}$ and $T_{exc}^{new,a}$ remain unknown. To estimate these unknowns, defining a tariff structure that respects the constraints set by the TICSI, it was decided to resort to mathematical optimization tools [37]. The objective function is represented by (5), which by (4) must tend to VRG_{conv}^{a}, respecting the following constraints to follow (7).

$$\begin{cases} T_{exc} \leq 6T_{red} \\ QF_{ACQ}^{new,a} \leq 20\% \cdot VRG_{conv}^{a}. \end{cases} \tag{7}$$

The first constraint of Eq. (7) is aimed at containing the progressiveness of the tariffs (with positive effects in favor of large families), while the second constraint derives from the application of a criterion recently elaborated by the EU jurisprudence, which requires relating the fixed tariff portion to the "burdens borne by the water distribution services to make it available to users, in sufficient quantity and quality, regardless of the actual consumption they make of it" (judgment of the Court of Justice in Case C-686/15) [35]. In particular, according to the National Authority, the charges connected to the activity of measurement, qualitative analysis and those relating to the safety of water supplies are covered by the fixed tariff portion.

Once the nature of the objective function is defined, it is clear that it is a linear programming problem. For its resolution, the simplex algorithm was used. This algorithm, which can be implemented with the Excel software using the "solver" command, makes it possible to estimate T_{exc} and $QF_{ACQ}^{new,a}$, and therefore to define the complete tariff breakdown even if the Convergence Regulatory Scheme is used.

5 Conclusions

In Italy, despite the efforts of the Regulatory Authority for Energy Networks and the Environment (ARERA) to improve the Integrated Water Service, a significant disparity in the management and implementation of investments still exists between certain areas, mainly located in the southern regions and islands, and the rest of the country. The inadequacies in the South are primarily due to limited management and organizational capabilities, rather than a lack of funding. This is especially true for those managements entrusted directly to municipalities that operate water services at an economic cost. Between 2016 and 2021, the per capita investments made by these economically managed systems showed an average value of €8 per inhabitant, with significant differences based on geographic location. While per capita investments in the Northwest and Northeast are significantly higher, with an average of €23 and €18 per inhabitant, respectively, the average per capita investment value in the central and southern regions is €7 per inhabitant [12].

To reduce the Water Service Divide, new regulatory provisions have recently been introduced. The National Authority introduced the Convergence Regulatory Scheme with the Water Tariff Methodology - MT3 to overcome the North-South differences and lead less efficient water operators towards the national standard. This scheme allows less efficient operators to apply a simplified system for defining the tariff multiplier ϑ. However, the introduced simplifications do not seem sufficient to carry out the complete articulation of the tariffs by consumption bands, as provided for by the Integrated Text for Water Services Tariffs (TICSI). To address this issue, a model is proposed to allow for the complete articulation of water tariffs and compliance with the constraints imposed by ARERA. The model, which uses the Simplex Method, makes it feasible to apply the provisions provided for by TICSI even to those managements that do not have tariff data or cost data. The proposed model aligns with the community objectives regarding the management of the water resource, which require water tariff schemes to fulfil four different and sometimes conflicting objectives: (i) ecological sustainability, (ii) economic efficiency, (iii) financial sustainability, and (iv) social equity/affordability. In particular, it allows the operator to adopt tariffs that encourage users to avoid wasting resources, in compliance with the "polluter pays" and "full cost recovery" principles.

In the context of sustainable urban projects and urban regeneration, sustainable water management practices are crucial [38]. These practices can help reduce the Water Service Divide and promote ecological sustainability, economic efficiency, financial sustainability, and social equity/affordability in urban areas [39].

The next goal of the research is to apply the model to a case study, quantifying with appropriate simulations both the financial effects on the operator of the water service as a result of the definition of tariff ranges carried out even in the absence of data and also by analyzing the sustainability of the model for the utilities.

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