

## **INTEGRATING SEASONALITY, SUPPLY AND DEMAND IN WATER PRICING MODEL: A CASE STUDY FOR CHATTOGRAM CITY**

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### **ABSTRACT**

Chattogram, the second largest city in Bangladesh is under immense pressure in its urban water supply system, which is attributed to rapid urbanization, the increased demand and inefficiencies in the provision and delivery of services. Chattogram Water Supply and Sewerage Authority's (CWASA's) uniform tariff system does not consider income and usage differences and thus makes water less affordable for low consumption users and offers no incentive for high users to conserve. As a result, the existing model fails to meet the key principles of Integrated Water Resources Management: efficiency, equity, and sustainability. The present study aims to design an advanced, data-driven block tariff model to examine the actual consumption patterns of Chattogram. The proposed model aims is expected to bring about a more sustainable and economically viable framework for urban water management in Chattogram by ensuring water pricing is aligned with the usage behaviour and cost of elements. In order to solve this issue, the study proposes a three-tiered progressive block tariff model that will bring in differentiated pricing based on consumption levels. The purpose of this system is to safeguard the low-income users, discourage excessive usage of water, and enhance the financial viability. The primary objective of the study is to come up with a data-based, context-dependent water pricing model for CWASA, based on five years (2020–2024) of billing data and primary surveys from 100 households. The unit cost of water production was calculated through a detailed financial analysis involving unit cost of operation and maintenance expenses, depreciation and yearly investment, which were all used to drive the tariff model. The proposed structure with blocks of 12, 27, and 50 Tk. /m<sup>3</sup> achieved a Benefit Cost Ratio (BCR) of 1.66, which proved to be financially viable and encourage fairness and conservation. The study can be implemented in the policy implications of the suggested tariff system to provide uninterrupted water supply, promote efficient utilization, and lead to the further discussion on the sustainability of urban water management in Chattogram city.

**Keywords:** *CWASA, water pricing, tariff, benefit cost ratio*

## 1. INTRODUCTION

Water forms a valuable resource to human well-being, environmental sustainability and socio-economic growth. Safe and sufficient water is one of the pillars of human development, but the sustainability of water in rapidly growing urban cities is a major problem. According to the recent research, the urban water shortage becomes more and more centred on governance failures and economic inefficiency instead of just physical availability of water (Wheeler et al., 2023). The cities of the South Asian region are experiencing the pressure of rapid urbanization, population growth, and other economic activities on the municipal water supply systems. The second largest metropolis in Bangladesh, Chattogram, is faced with an increasing disparity between the demand and supply of water which is aggravated by the ageing infrastructure, production capacity, and financial limitations. Nevertheless, despite the efforts, the current tariff system of Chattogram Water Supply and Sewerage Authority (CWASA) is homogeneous, and it is not responsive to the differences in consumption behavior, economic capacity, and availability of resources. This type of flat-rate pricing does not permit the recovery of costs, offers little incentive to conserve, and undermines the long-term sustainability of services (Kashem & Mondal, 2022).

The issue of water pricing has been identified as a major instrument in controlling the demand of water, which encourages effective utilization and sustainable distribution of resources. There is empirical analysis of tariff reform that is demonstrable to have certain effects on the pattern of consumption by households and utility cost recovery (Güven & Başaran, 2024). Early model of water pricing had frequently been simplistic in nature that did not consider differences in consumption level or costs of supply. Water pricing models have changed since the late 20th century to complex volumetric and tiered water pricing models as opposed to simple flat rate water pricing models. The significance of water pricing model has grown with increased focus on Integrated Water Resources Management (IWRM) with wide scopes like equity, efficiency and sustainability (Rogers, 2002). International practice demonstrates that progressive tariff schemes in particular the increasing block tariffs (IBT) can be used to equalize affordability and cost recovery given that they are designed and adjusted to local conditions (Boland, 1998).

Water pricing in Bangladesh has been low and highly subsidized. Indicatively, others have attempted to apply DWASA to a block tariff system, but research indicates that it is not able to cover all the operation and maintenance costs as it does not bill efficiently, experiences losses and unprofitable pricing. Equally, due to increasing pressure of demand and cost of infrastructure, CWASA is incurring an increasing financial burden necessitating a new and more responsive tariff structure. In their study Kashem & Mondal, 2022 suggested a two block tariff model in the Tejgaon region of Dhaka as a part of an integrated water resources management (IWRM) strategy. Their findings showed a possible decrease in water consumption, significant increase in utility revenue and low-income groups will receive lower bills of up to 67 percent. These results point to the existence of block tariffs as a way to balance conservation and affordability. Multi-objective pricing models can be used to derive optimal water tariff structures that balance cost, welfare and sustainability (Caravaggio et al., 2024). WaterAid also tested a progressive tariff in smaller towns such as Paikgachha, Khulna, which managed to keep the costs affordable and enhance the financial sustainability (Muniruzzaman, 2017). Such strategies have been institutionalized in countries such as South Africa with their constitutional right to water guaranteeing the right to water and Chile had introduced means-tested subsidies to help the poorest families without distorting the pricing scheme (Komives et al., 2005).

The financial viability and fairness of access are the focus of policy frameworks in Bangladesh as stated in the National Water Policy Ministry of Water Resources Government of the People's Republic of Bangladesh, 1999. Another point that is supported by IWRM principles is that water prices should allow equitable distribution, conservation, and the recovery of costs in the long term (Rahaman & Varis, 2005). These recommendations demonstrate the necessity to implement the pricing policies which reflect the local hydrological, socio-economic, and institutional realities.

This study constructs a progressive and three-level block tariff plan of CWASA on the basis of the five years of billing information (2020-2024) and the household questionnaires. It combines the segmentation of users, seasonal usage factors, and the full-cost cost-accounting, including both capital investment that is annually amortized, to establish a revenue-sufficient and socially acceptable tariff. By linking block ranges to real consumption distributions and implementing a set of IWRM principles, the study offers a useful and scalable tariff framework that can be used to promote affordability, cost recovery, and responsible water use in high-growth urban settings.

## **2. METHODOLOGY**

A mixed-method method was implicitly assumed to provide the research objectives, including both quantitative and qualitative analyses to obtain a thorough deliberation of water consumption behaviour, cost structures, and tariff sensitivity among the consumers of Chattogram Water Supply and Sewerage Authority (CWASA). The quantitative element was concerned with measurable variables like monthly water use, the amount of bills and the costs of operations, which were obtained through the official records of CWASA, and analysed within Microsoft Excel to thoroughly model numerically and financially different tariffs, see-through consumption trends, seasonal fluctuations, and financial viability of various tariffs. Simultaneously, the qualitative part consisted of socio-economic household surveys that provided background information about affordability, use and views of fairness of prices. The analysis was conducted as in the CWASA service area that entails the Chattogram Metropolitan Area and the water demands in the area have escalated due to the rapid urbanization. It also targeted residential neighbourhood to cover distribution of various socio-economic profiles to look at the correlation between income and household characteristics and reaction to tariff change and water affordability. The area is also of high significance to the example of sustainable water pricing and resource management.

### **2.1 Data Collection**

#### **2.1.1 Sample Size Selection**

In order to have spatial representativeness in the study, the area sampled was distributed by identifying four or five residential buildings in various locations in the city in an attempt to derive the whole of the Chattogram WASA (CWASA) service area. The aim behind this strategy is to sample water-use attributes in a broad geographical scope of CWASA-served zones as opposed to sampling locality in a few places. The number of households used was not more than 100 households because of time limitations and the logistical burden of collecting physical field data. Although the sample size was rather small, this method allowed incorporating households in almost all big CWASA service zones which resulted in a balanced and geographically inclusive study resource to analyse domestic water consumption and response to tariffs. The study was executed using both primary and secondary sources of data to make it more reliable, consistent and comprehensive

#### **2.1.2 Primary Data**

A systematic household interview was conducted on 100 households in the CWASA service region. Besides the billing records, primary interviews or survey were carried out with the residents to provide the following information:

- Average monthly water bills and consumption.
- Average number of people per household.
- Household income and size.
- Ownership of water-related appliances (e.g., washing machines, pumps).

- Perceptions of affordability, satisfaction with CWASA services, and awareness of tariff changes.

Data were collected through interviews to ensure accuracy and clarity. This kind of data made it easy to comprehend socio-economic traits with actual consumption behaviour that determines the water demand and the readiness to pay water uses.

### 2.1.3 Secondary Data

The secondary data was collected using the official records and published reports of CWASA. The dataset included:

- Five-year billing records (2020–2024) for various categories of users.
- Operation and Maintenance (O&M) expenditures.
- Capital investment costs and ongoing project expenditures.

These datasets were used to establish consumption baselines, evaluate cost recovery ratios, and support the development of tariff scenarios.

## 2.2 Data Analysis Procedure

The analysis of the data was done in numerous steps, with the help of Microsoft Excel to compute, imagine, and financially model the data.

Firstly, the monthly average consumption was taken into account of each household on the basis of billing data obtained. A combination of these values in all households surveyed was then done to determine seasonal differences and patterns of consumption.

Then a financial analysis was conducted to assess the cost recovery performance of CWASA. The Benefit-Cost Ratio (BCR) was also an important measure of financial sustainability that was defined as::

$$BCR = \frac{\text{Annual Revenue}}{\text{Annual Cost}} \quad (1)$$

Here, annual revenue will be the amount earned as a result of water bills in a year and annual cost will be the total amount spent as both Operation and Maintenance (O&M) and annualized cost spent in developing the infrastructure.

Before analyzing, data was scrubbed and consistency checked to guarantee logical consistency in variables (e.g. bill amount and consumption volume). The findings were then applied in order to test various tariff arrangements and estimated their financial and social implications.

## 2.3 User Segmentation and Block Design

In order to determine the influence of tariffs more precisely, households were divided into three user blocks which were based on consumption. This segmentation indicates the variation in the behavior of usage and affordability.

Table 1: Classification of Blocks Based On Consumption Range

Block	Consumption Range (m <sup>3</sup> /month)	User Share (%)	Purpose / Typical Users
1	0–100	26	Basic needs, low-income households
2	101–400	56	Average domestic users

3	>400	18	High-consumption or affluent users
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The former block reflects on low-income consumers who mainly utilize water in ways that are not luxurious like drinking, cooking, and sanitation. The second block comprises majority of households whose usage is moderate and the third block is high volume consumers where the study tested the increasing block tariff (IBT) structure where the higher the consumption levels the higher the rate. More explicitly stated in Bangladesh, the National Water Policy Ministry of Water Resources Government of the Peoples Republic of Bangladesh, (1999) prioritizes cost recovery and affordability as key factors and promotes cross-subsidization policies to serve the low-income consumers. Besides, the Government of the People Republic of Bangladesh Water Resources Planning Organization, (2001) suggests the use of progressive tariff systems as a way of enhancing financial sustainability and ensuring efficient use of water. A combination of this policy directions with the analysis of the consumption empirically, has varied the selected block ranges of 0–100, 101–400, and >400 m<sup>3</sup> for this study.

## 2.4 Cost Structure and Unit Production Cost

Understanding the CWASA’s operational cost structure was essential for precise financial modelling. Based on financial reports of CWASA, the average unit production cost was estimated at approximately Tk. 20 per cubic meter (m<sup>3</sup>). All major cost components, including:

- Electricity and fuel for pumping and treatment.
- Chemicals for water purification.
- Labor and administrative expenses.
- Depreciation of equipment and infrastructure.

In addition to O&M costs, the analysis incorporated annualized investment costs for ongoing and recent infrastructure projects. The annualization was calculated using the standard annuity formula:

$$A = \frac{I \times i \times (1+i)^n}{(1+i)^n - 1} \quad (2)$$

Where  $I$  = Total investment,  $i$  = Discount rate,  $n$  = lifespan of project in years.

Using this approach, the combined annualized investment for CWASA’s major capital works was estimated at approximately Tk. 9.36 billion, which was added to O&M expenses to compute the total annual cost. This comprehensive costing approach provided a realistic basis for evaluating the financial sustainability of different tariff scenarios.

## 2.5 Tariff Scenario Development

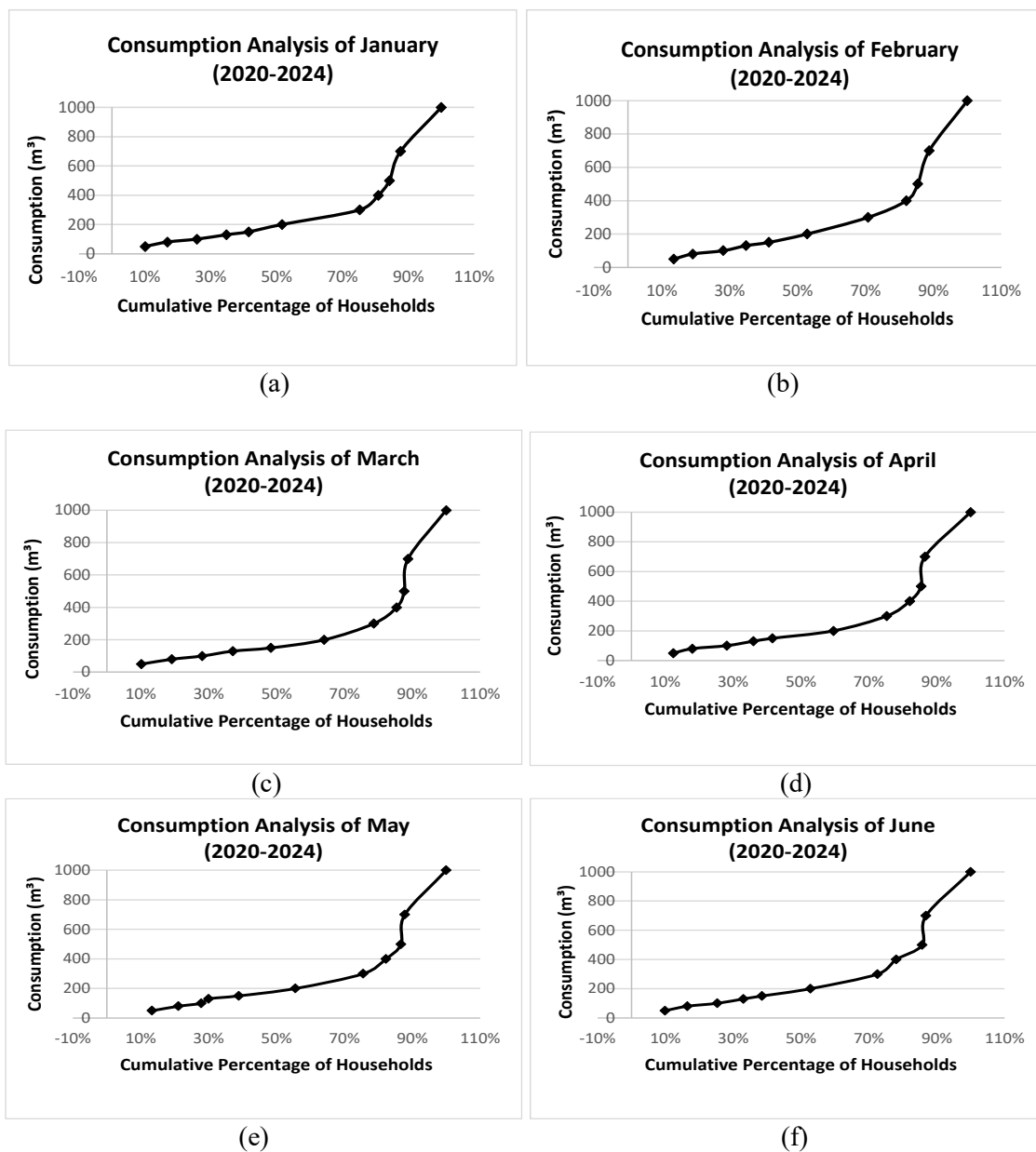
In order to analyze the implication of alternative pricing structures, tariff scenarios were modeled using approximated costs of supply and the consumption pattern of households with water. Block-wise tariff combinations were used to simulate these scenarios and evaluate their impact on revenue creation, affordability and the Benefit Cost Ratio (BCR). A bottom-up approach was followed in adoption of an increasing block tariff (IBT). Under this arrangement, the initial consumption block would be priced low to make it affordable to the low income households, and the successive blocks would be charged small tariffs of increasing amount to help conserve water and allow the collection of cost. In this context, different tariff schemes were experimented, such as 12-30-35 Tk/m<sup>3</sup>, 12-28-45 Tk/m<sup>3</sup>, 12-30-50 Tk/m<sup>3</sup>. To obtain block specific revenues, the number of consumers in each category and the respective volumes of water consumption were added together to obtain the block specific revenues of each tariff set-up. The annual average revenue was compared to total annual cost of water supply to calculate BCR of each situation. This was then assessed on three criteria which are interrelated, namely: (i) financial feasibility to attain BCR of at least 1.0; (ii) equity and affordability, and this will be guaranteed by charging a subsidized first block to the low-income users; and (iii) efficiency and conservation, which

will be enforced by higher marginal tariffs with increased consumption rates. The scenario of the tariff that was preferred was that which best balanced affordability with financial sustainability, conservation incentives and full cost recovery.

### 3. RESULTS & DISCUSSIONS

#### 3.1 Household Water Consumption Pattern Analysis

The analysis of five years (2020–2024) of CWASA billing data revealed that overall household water consumption in Chattogram remained relatively stable throughout the year. Seasonal variations were minor—consumption increased slightly during pre- and post-monsoon periods and declined during the monsoon months due to rainfall and reduced household demand.



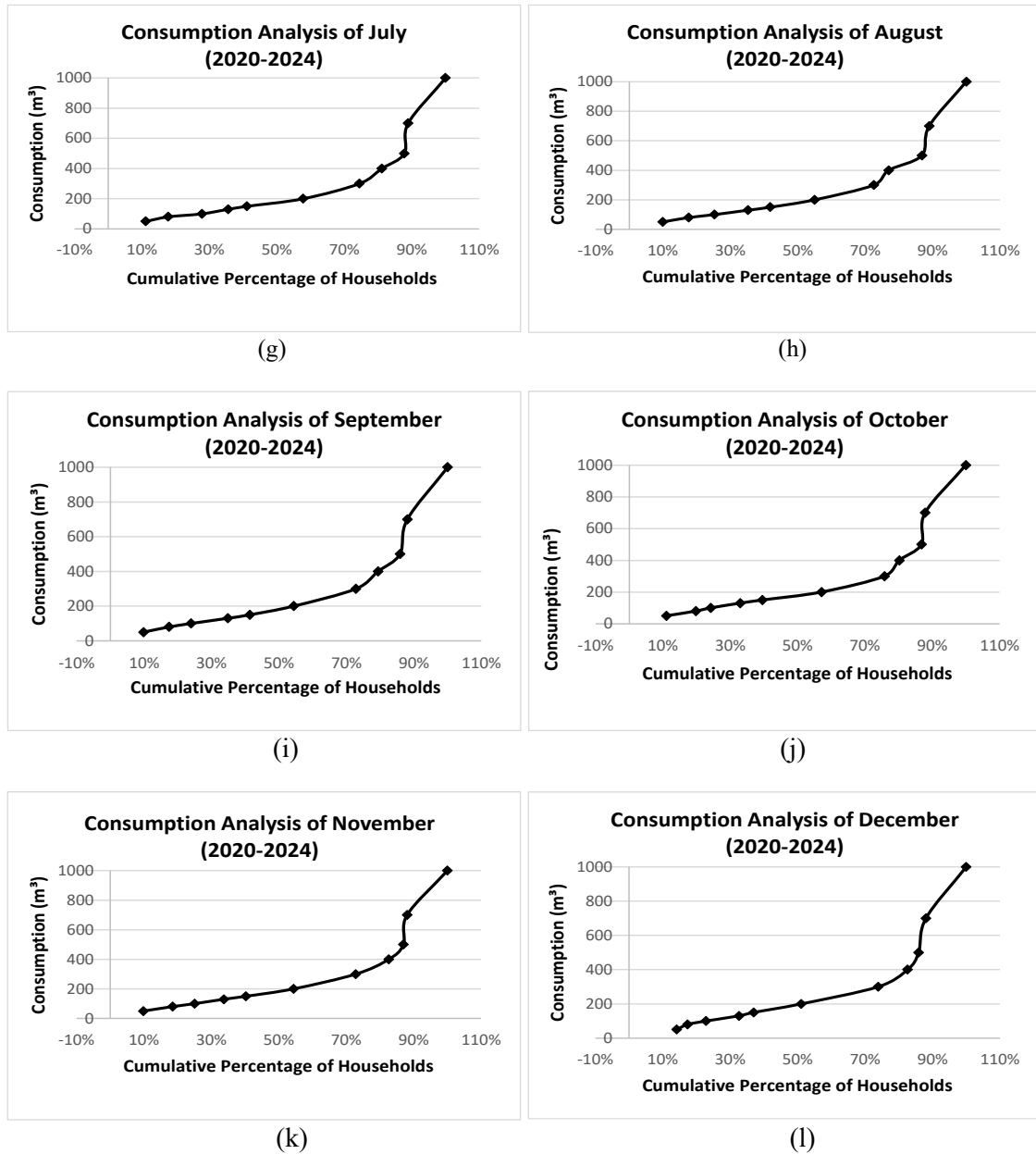


Figure 1: Consumption analysis of; (a) January, (b) February, (c) March, (d) April, (e) May, (f) June, (g) July, (h) August, (i) September, (j) October, (k) November, (l) December.

These seasonal trends suggest that while there are no extreme consumption imbalances, slight variations exist that correlate with climatic cycles. Relevant studies show that stable seasonal demand facilitates the efficiency of non-seasonal progressive block tariffs in urban settings (Lee et al., 2024). The steady consumption pattern overall supports the feasibility of implementing a uniform block tariff system without the need of adjustments of seasonal prices. Moreover, the slight reduction in monsoon consumption implies potential opportunities for promoting rainwater harvesting and water conservation promotions during wet months, which could help further reduce supply pressure on CWASA.

### 3.2 User Segmentation and Block Distribution

Based on consumption per month, households were grouped into three different categories as presented in Table 1

- Block 1 (0–100 m<sup>3</sup>/month): 26% of users, representing basic domestic use.
- Block 2 (101–400 m<sup>3</sup>/month): 56% of users, representing average consumption.

- Block 3 (>400 m<sup>3</sup>/month): 18% of users, mostly higher-income households or large buildings. Such a breakdown is a direct reflection of actual consumption behaviour and is necessary to ensure that rates of tariffs are based on household income and consumption patterns. It offers a persuasive ground on how to come up with an equitable and economically viable progressive block tariff system.

### 3.3 Tariff Scenario Trials and BCR Results

Several tariff combinations were assessed to determine the most financially sustainable and socially acceptable model.

A sensitivity analysis of price sets is given in the table:

Table 2: Sensitivity Analysis on Different Combination of Tariffs

Price Set (First block, second block, third block)	BCR	Comments
12,30,35	1.45	Moderate revenue, affordable but lower cost recovery
12,30,45	1.66	Strong revenue generation, maintains affordability for basic users, optimal cross-subsidy
12,30,50	1.75	Highest BCR, but potential social acceptability issues in higher block
15,25,35	1.37	Lower BCR, moderate overall revenue
15,30,35	1.51	Balanced, slightly less effective cross-subsidy

Among these, the Tk. 12–30–45/m<sup>3</sup> model achieved the best overall performance with a Benefit-Cost Ratio (BCR) of 1.66, indicating sufficient revenue to recover full production costs while keeping the first block affordable for low-income consumers. This pricing design also provides incentives for efficient water use among high-consumption groups.

### 3.4 Financial and Cost Analysis

The average cost of a single unit production was estimated to be Tk. 20 per cubic meter, that is, incorporating operation and maintenance cost, depreciation cost, and annualized costs of investment. This figure is close to those of CWASA in terms of its internal financial reports. The tariff proposed will result in full cost recovery and a slight surplus to invest in infrastructure. The effect of cross-subsidization, which includes high-use consumers to the benefit of low-use households, increases social equity and sustains finances. Generally, the model strikes a balance between three objectives, which include cost-effectiveness to simple users, economic sustainability to CWASA and conservation among the upper consumers.

### 3.5 Policy and Environmental Implications

The model proposed will be in line with the National Water Policy (1999) and the Integrated Water Resources Management (IWRM) model that puts stress on equity, efficiency and sustainability. It also promotes conservation of the environment by deterring overused consumption of water in higher blocks and promotes practice of water conservation like rainwater collection.

The model offers a model to be replicated by other urban utilities in Bangladesh through the fusion of financial and environmental views, which have encountered the same issue of supply and demand. Recent policy-directed research suggests that progressive tariffs should be used together with targeted

social protection systems in order to achieve both financial sustainability and social equity (Nauges et al., 2025). It is a change in the flat-rate tariffs to more data-driven, fair, and sustainable water management.

#### **4. CONCLUSIONS**

The research has made it clear that water usage in Chattogram is quite stable over the year and there is some slight seasonal variation, which suggests that the use of a constant annual tariff is more appropriate compared to seasonal pricing structure. The analysis of user segmentation showed that there are three different consumers groups, and it is necessary to introduce a progressive tariff system which would indicate different usage habits and socio-economic statuses. Using sensitivity analysis of various tariff regimes, tariff structure was the most efficient, giving a BCR of 1.66, and making it recover all costs and be affordable to the low-income earners who should be the main beneficiaries of this change. The approximated cost of production of Tk. 20/m<sup>3</sup> was in close agreement with the internal estimates of CWASA which further enhanced the financial integrity of the model. The proposed tariff can increase revenue stability, as well as promote responsible consumption by the high-consumption users by implementing a cross-subsidization strategy, where the high-consumption users subsidize the low-income households. Besides this, the metering accuracy and billing enforcement should be enhanced by the policymakers so that the progressive tariff system is effective and the revenue leakage is minimized. Water tariff reforms should be well supported with a system of public awareness and stakeholder engagement programs to enhance better consumer acceptance and water conservation behavior. Last but not least, CWASA ought to improve its data collection, monitoring mechanisms on consumption, losses, and service quality, which will enable the adjustment of tariffs on the basis of evidence-supported services and long-term planning in the environment of increasing urbanization and climatic stress. All in all, the results prove that a progressive block tariff based on data is technically and socially suitable to CWASA and offers a roadmap of urban water utilities in Bangladesh with the intention to balance equity, sustainability, and financial efficiency.

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#### **DECLARATION OF THE USE OF AI**

The authors state that it was only the artificial intelligence (AI) tools, which helped to edit the language, correct grammar, and enhance clarity and academic writing style of the manuscript. The research design, data collection, data processing, financial analysis, tariff modeling, results analysis interpretation, and conclusions have not been done using AI tools. The authors carried out all the analyses, calculations, and findings in this work individually and confirmed the information.

#### **REFERENCES**

- Boland, J. J. (1998). *The Political Economy of Increasing Block Tariffs for Water in Developing Countries The Political Economy of Increasing Block Tariffs in Developing Countries*. <https://www.researchgate.net/publication/46465541>
- Caravaggio, A., De Cesare, L., & Di Liddo, A. (2024). Optimal water tariffs for domestic, agricultural and industrial use. *Annals of Operations Research*, 337(3), 1135–1165. <https://doi.org/10.1007/s10479-024-05822-y>
- Güven, M. A., & Başaran, A. A. (2024). Household Water Consumption and Tariff Structure: The Analysis of Türkiye's Three Metropolitan Cities. *Sosyoekonomi*, 32(59), 151–172. <https://doi.org/10.17233/sosyoekonomi.2024.01.07>

- Kashem, S., & Mondal, M. S. (2022). Development of a Water-Pricing Model for Domestic Water Uses in Dhaka City Using an IWRM Framework. *Water (Switzerland)*, 14(9). <https://doi.org/10.3390/w14091328>
- Komives, K., Foster, V., Halpern, J., & Wodon, Q. (2005). *Water, Electricity and the Poor Who Benefits from Utility Subsidies?*
- Lee, J., Nemati, M., Allaire, M., & Dinar, A. (2024). The impact of pricing structure change on residential water consumption: A long-term analysis of water utilities in California. *Water Resources and Economics*, 46. <https://doi.org/10.1016/j.wre.2024.100240>
- Muniruzzaman, I. K. ; M. S. ; I. K. and K. (2017). *Taking a Multidimensional Approach to Small Town Water Supply: The Case of Paikgachha.*
- Nauges, C., Wheeler, S. A., & Grafton, Q. R. (2025). "Water pricing and markets: Principles, practices and proposals" *Water Pricing and Markets: Principles, Practices and Proposals.*
- Rahaman, M. M., & Varis, O. (2005). Integrated Water Resources Management: Evolution, Prospects and Future Challenges. *Sustainability: Science, Practice and Policy*, 1(1), 15–21. <https://doi.org/10.1080/15487733.2005.11907961>
- Rogers, P. (2002). Water is an Economic Good: How to Use Prices to Promote Equity, Efficiency, and Sustainability. *Water Policy*, 4(1), 1–17. [https://doi.org/10.1016/S1366-7017\(02\)00004-1](https://doi.org/10.1016/S1366-7017(02)00004-1)
- Wheeler, S. A., Nauges<sup>2</sup>, C., & Grafton<sup>3</sup>, R. Q. (2023). *Water Pricing, Costs and Markets.*