Technical Note on Pricing of Rural Drinking Water

Gopal Naik and Prerona Sengupta

February 2024

Jal Jeevan Mission Cell

Indian Institute of Management Bangalore

Technical Note on Pricing of Rural Drinking Water

Keywords

1. **Fixed cost:** These are Costs incurred when constructing or purchasing fixed assets of a long-term nature such as construction of tubewell/Jack well, pump, over-head tank, pipeline, etc. These costs are recognized over time via depreciation or amortization and remain the same irrespective of the extent of water supplied delivered.
2. **Operation and maintenance cost:** These are the regular costs incurred to maintain its day-to-day operations. These expenses are recurring and occur frequently such as salaries and wages, electricity, etc and vary with the extent of water supplied.
3. **Annualized fixed cost:** The annualized fixed cost is obtained by computing the annual amortization at a risk-free interest rate.
4. **Cost per kl:** Is the full cost of supplying one kl of water to the households. This helps to implement charging water on volumetric basis.
5. **Cost per household**: It is the full cost of supplying water to individual household per month or per annum, which is a flat rate pricing.
6. **Surplus/Deficit over O&M cost per annum**: Surplus/ Deficit over operation and maintenance cost reflects the extent to which the user charges collected in a year has been successful in recovering the operation and maintenance cost. In other words, it provides insights on whether the user charges collected from all the households are sufficient to cover the cost incurred for operating and maintaining the piped water delivery system.
7. **Surplus/ Deficit over total cost per annum**: Surplus/Deficit over the total cost per annum reflects the extent to which the user charges collected in a year have been successful in recovering the full (total) cost. In other words, it provides insights on whether the user charges collected from all the households are sufficient to cover the total cost incurred.
8. **Share of operation and maintenance cost in total cost (%):** The percentage share of O&M cost in total cost and it helps to understand how critical it is to supply to as many households as possible. For example, if the share O&M cost is low implies fixed cost share is high and therefore supplying to more households can substantially reduce per household cost.

Need for Pricing Drinking Water

Developing a Piped Drinking Water System in rural areas to provide adequate and quality water with reliable supply is considered crucial to improve livelihood condition in terms of reducing drudgery of collecting water from distant places, ensuring safe drinking water, improving health of people, facilitating better education of particularly girl child, improving labour market participation, increasing employment opportunities, and enhancing economic and social status of rural people. In areas suffering from water scarcity and or problems with respect to water quality, are likely to realize significant value directly or indirectly from the establishment of a good drinking water system. Realizing this, Jal Jeevan Mission (JJM) is being implemented since 2019 throughout India to connect every rural household with functional tap water by establishing appropriate water supply system either for a single village or multiple villages depending on the availability of quality of water resources. It is envisaged that the establishment of such a system will be mainly done through the funding of central and state governments whereas the operation and maintenance must be done by the Village Water and Sanitation Committee at the habitation level and the expenditure must be met through service charges and other revenues. This requires levying user charges to every household on some basis such as extent of use or simply flat rate on a per household basis. This note provides the conceptual understanding that needs to be considered while determining such user charges.

Determination of water charges is akin to deciding prices for goods and services in the marketplace. If the markets for goods and services are competitive or contestable, the price is determined solely by the market forces of supply and demand, no individual participant has the power to influence prices and the resultant price is considered giving maximum welfare to the society as it perfectly matches supply and demand, and the competition eliminates deadweight loss. In other market structures such as monopoly, monopsony, duopoly, etc., the price is determined by the seller or buyer and is likely to create social welfare loss or deadweight loss. Piped drinking water supply systems, because of the nature of infrastructure needed such as fixed tank and pipeline networks to deliver water, are likely to create local monopoly for the service provider who, in the absence of any regulatory mechanism will determines the prices and is likely to generate monopoly profit and lead to social welfare loss. For an essential commodity like drinking water where the demand is likely to be inelastic, pricing with such market power could be substantially higher than competitive price and the community can suffer significant deadweight loss. For this reason, it is advocated that the drinking water system be run by public agencies on a no-profit-no-loss basis, not by for-profit private players. The immediate option available in the rural areas is either the government itself runs the system or allow village community to run the system. National or State Governments operating systems at village level are likely to be expensive as effective checks and balances may need creation of heavy superstructures and more likely inefficient as the services may not match the requirement of the people. For these considerations, JJM advocates for communities/local governments to be involved in the process of implementation and take over the operational and maintenance function of the rural piped drinking water systems. JJM envisages community involvement right from the beginning of the implementation at the time of preparation of village action plan, preparation of detailed project report, infrastructure development and contribute 10 per cent of the investment cost of the project. This contribution and involvement are expected to make the village community take ownership of the assets and manage them efficiently at the construction as well as operation and maintenance stages. At the construction stage community provides input on the necessary infrastructure and the quality of construction so that the cost of investment can be reduced as well as with the better-quality infrastructure the repair and maintenance needs will be lower which would help in better management of the system. In the general environment of poor common property management at the community level, and the need to make piped drinking water system work efficiently to meet the essential drinking water need, such an approach to involve community from the very beginning of the implementation is expected to address concerns about the functionality and sustainability of the water delivery system.

User Charge

Providing large public infrastructure projects, like JJM, are often implemented with the understanding that costs are recovered partially or fully towards the money that is borrowed from lending institutions or invested through public funding. Though, the full cost recovery helps in creating a corpus that can ensure timely repair as well as replacement of fixed assets can be done as needed, at the very least such projects envisage recovering operations and maintenance expenses for sustenance.

Water as an economic good necessitates ensuring a proper balance between supply and demand. The goal of achieving a balance between water supply and demand can be accomplished through an efficient pricing approach that has a significant impact on the cost recovery of water service and operation. Cost recovery through user charges, is also a method for improving water allocation and encouraging conservation. Additionally, prices that appropriately reflect water's economic, or scarcity value provide consumers with information that they can use to make decisions. Water pricing can influence water use and efficiency at both the individual and community levels. Thus, a pricing policy may be the most effective tool for balancing the water supply and demand and achieving the desired financial and economic outcomes if it is implemented appropriately (Dinar & Subramanian, 1998). It is a useful method for encouraging consumers to utilize water efficiently while considering water productivity or value of water (Economical, Political, and Social Issues in Water Resources, 2021). While there is a certain amount of water individuals and households need to meet the daily needs, the net demand for a piped water system also depends on the availability of alternative sources of water at the household level and their quality. JJM prescribes a supply of 55 litres of piped water per capita per day. If there is good quality of water already available in sufficient quantity within individual's premises, the demand for piped water from the community level delivery system is likely to be low and the value attached to water will also be low. Water availability may also vary depending on the seasons. In high rainfall areas, during the rainy season, the demand for water from the piped water system is likely to be low. The management of piped water system needs to consider these factors while arriving at appropriate pricing either seasonally or annually.

Conceptual Framework

The Demand for Piped Drinking Water

Demand for any product or service by an individual consumer is said to be determined as the individual consumer maximizes the usefulness (utility) of consuming the good/service subject to her/his budget constraint that sets the expenditure on the good/service equal to the set budget. The demand curve is a downward sloping curve representing the inverse relationship between price and quantity demanded. While purchasing a commodity, a rational consumer compares the price of the commodity with the utility she receives from it. When the monetary value of marginal utility (MU), the utility derived by consuming on additional unit of a commodity/service(x), is higher than its price P, that is, $MUx > Px$, the consumer would demand more and more units of the commodity until $MUx = Px$ or when the equilibrium condition is reached. According to the law of diminishing marginal utility, as the consumer consumes more and more units of a particular commodity, the marginal utility starts to diminish after a certain amount of consumption.

Figure 1 Demand and marginal revenue

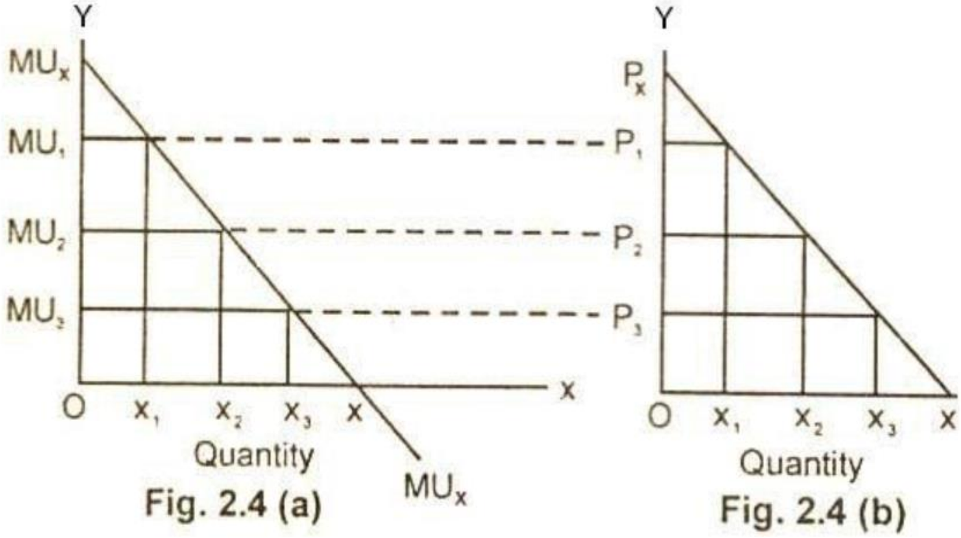


Figure 2 Derivation of the demand curve

In figure 2.4 (a) MUx is negatively slopped indicating that the marginal utility of good x diminishes as the consumer acquires more of it. Accordingly, as the price of the good x decreases, the quantity demanded increases 2.4 (b). At X_1 quantity, the marginal utility of a good is MU_1. This is equal to P_1 the price consumer is willing to pay. At this price, the consumer demands OX_1 quantity of the commodity. In the same way X_2 quantity of the good is demanded at price P_2. Thus, as the consumer increases consuming more and more units of the commodity, the utility diminishes which results in the downward sloping demand curve in figure 2.4(b). A demand curve graphically represents the inverse relationship between the quantity demanded and the price of a particular commodity in a given period of time.

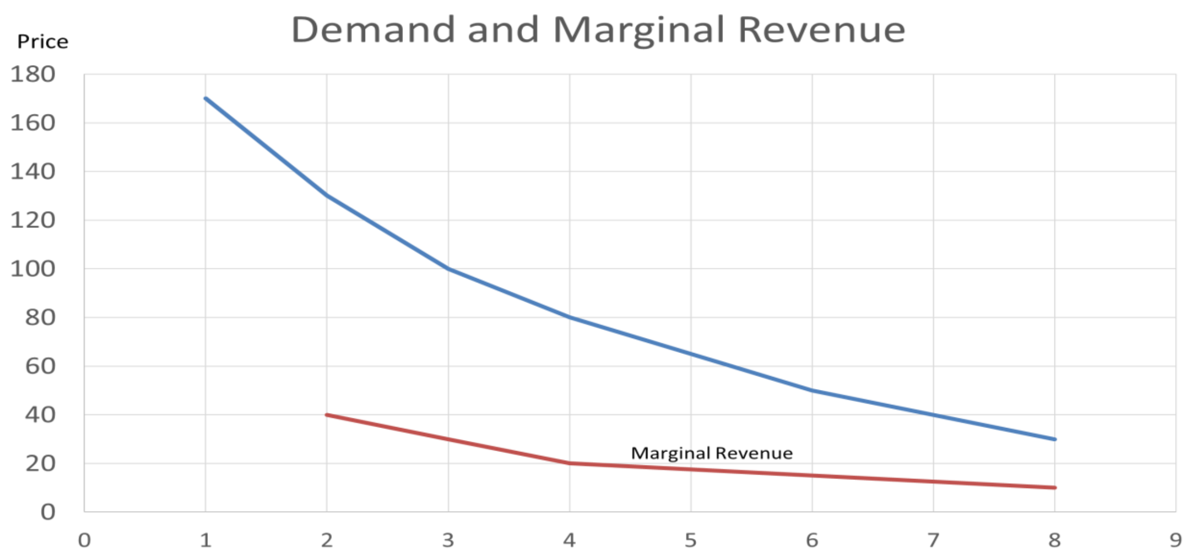
Construction of a demand curve

To demonstrate the construction of a demand curve, a demand schedule is represented as below:

In a study to find out the willingness to pay for drinking water supply the following representative individuals indicated the maximum price they would pay per month. Shankar Rs 50; Radha Rs 80; Kiran Rs 170; Dhiraj Rs 130; Smitha Rs 30; Lisa Rs 50; Nageena Rs100 and Sally Rs 30. With this data we can construct a demand curve.

Table 1. Demand Schedule

Price	Number	Demand	Marginal Revenue
30	2	8	-
50	2	6	10
80	1	4	15
100	1	3	20
130	1	2	30
170	1	1	40



Elasticity of the demand

Elastic demand or supply indicate that the quantity demanded or supplied responds to price changes in a greater than proportional manner (the ratio of change in demand with respect to change in price is greater than one). An inelastic demand or supply is one where a given percentage change in price will cause a smaller percentage change in quantity demanded or supplied (the ratio of change in demand with respect to change in price is less than one). Inelastic demand indicates that the good/service is essential.

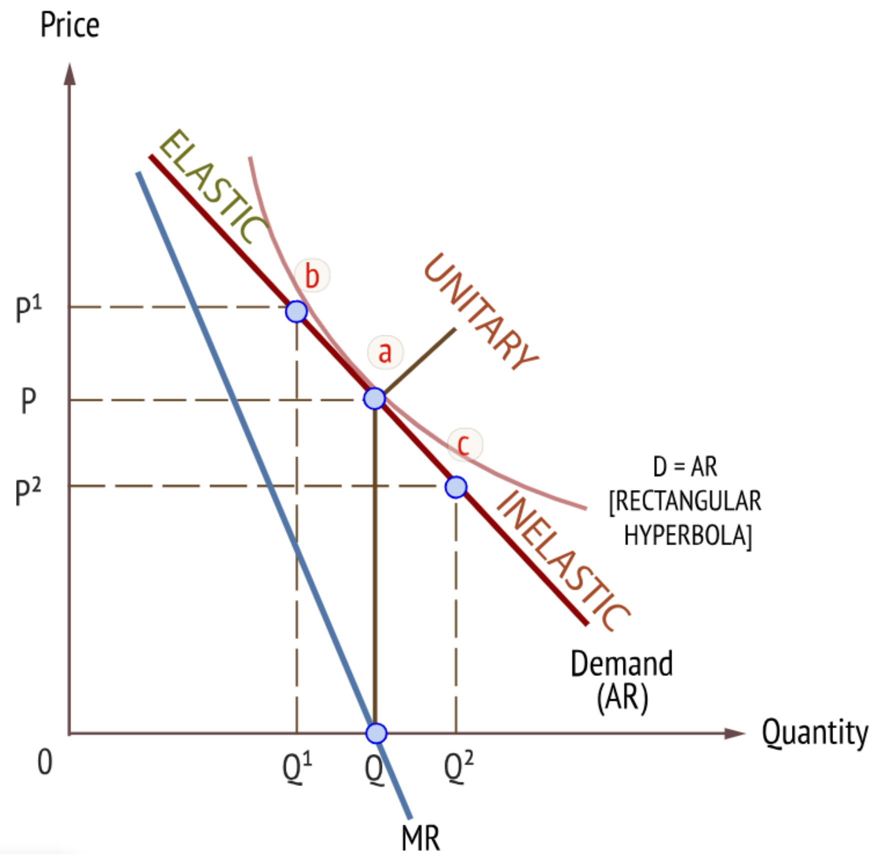


Figure 3 Elasticity of demand curve

Some studies have found the price elasticity of demand ranges from -0.15 to -0.52. In other words, water is inelastic to price increase because water is a basic need (Nieswiadomy, 1992; Olmstead et al., 2007)

The Supply Curve

The aim of a rational producer-seller is to maximise profit (Π), which is the difference between Total Revenue (TR), which is the revenue generated by selling Q amount of the product/service at price P and Total Cost (TC) which includes various items of Fixed (FC)as well as Variable Costs (VC). That is,

Π=TR-TC

Profit maximization is level of output is obtained when the revenue generated from an additional unit of good/service, Marginal Revenue (MR) is equal to cost of producing that unit, Marginal Cost (MC), that is,

MR=MC.

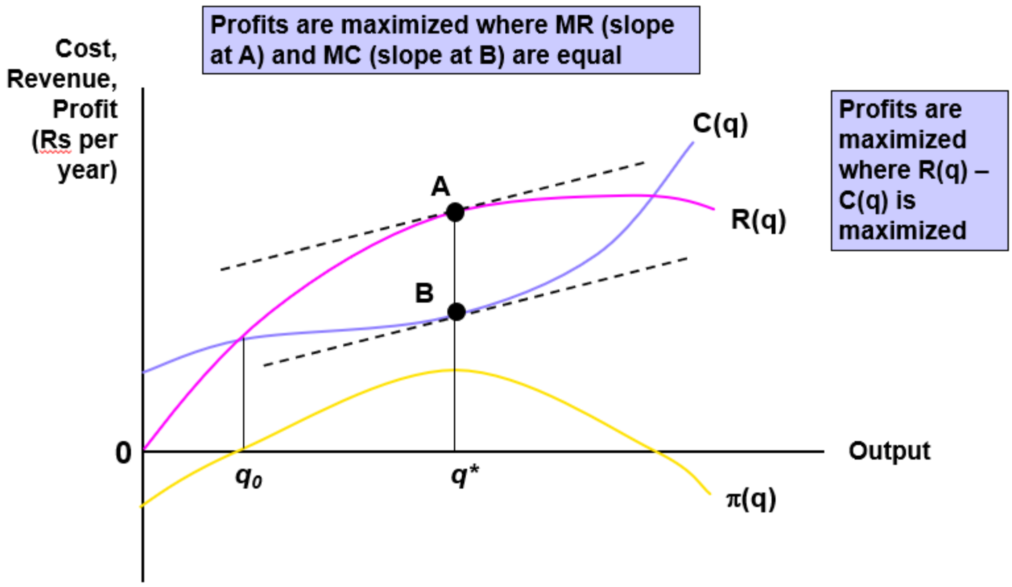


Figure 4 profit maximization

MR refers to the change in total revenue by the unit change of quantity and MC refers to the change in total cost for a unit change in quantity. Therefore, individual producer's supply curve is the MC curve as it indicates the quantity that can be supplied at a normal return for a given price. Market supply curve is the aggregation of all individual supply curves.

Profit is maximized at the point at which an additional increment to output leaves profit unchanged.

$$\pi = R - C$$

$$\frac{\Delta \pi}{\Delta q} = \frac{\Delta R}{\Delta q} - \frac{\Delta C}{\Delta q} = 0$$

$$= MR - MC = 0$$

$$MR = MC$$

At different output prices the profit maximizing output level to be produced changes as shown in figure 3.

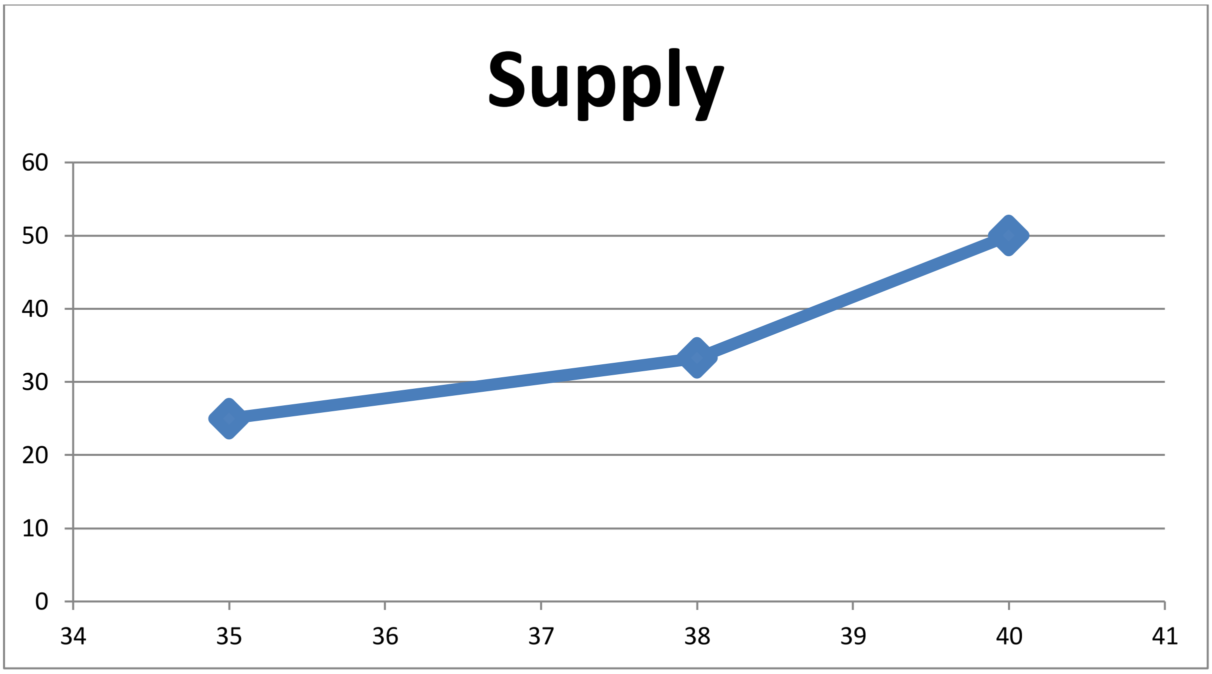


Figure 5 Firm's supply curve

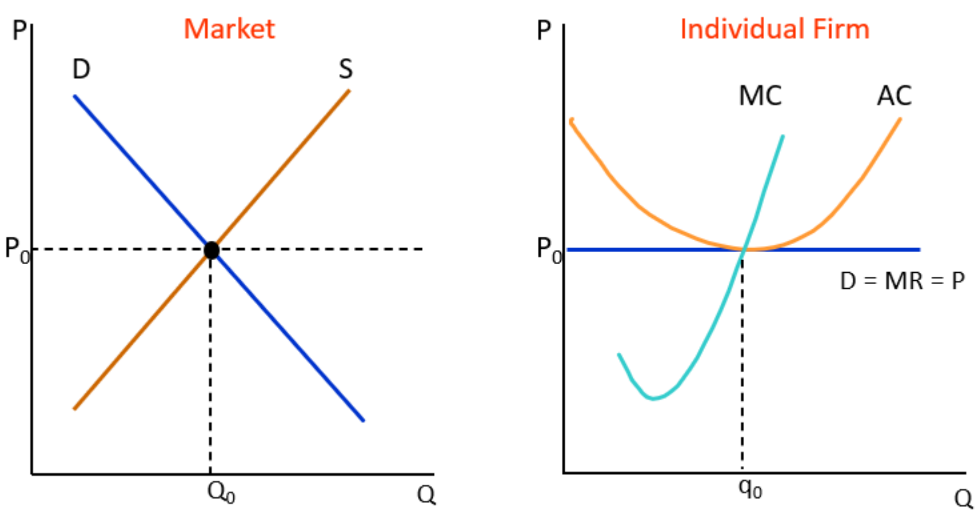
Market Structure and Pricing

Pricing goods and services also depends on the market structure apart from supply and demand factors. There are different types of market structures which determine the prices of the commodity according to the distinct characteristics they possess. Some common market structures apart from competitive markets are Monopoly, Monopolistic Competition and Oligopoly. The characteristics of the market are given in table 1. Monopolistic competition and oligopoly are forms of market that deals with differentiated goods that are distinguished goods which have unique characteristics supplied by different producers. Perfect competition and monopoly market structures is meant for homogenous goods or a single good which is more appropriate in this case for supplying piped drinking water. In water abundant places where many households are likely to have their own well might resemble a competitive market though the extent of transactions may be low, whereas water supplied through pipes or functional household tap connections to every household from a common tank/source may have local monopoly by the supplier. An industry with one supplier without any close substitute suppliers will have the monopoly or have market power to price the good. Monopoly is, thus, a price maker, which means that it decides its own prices. Whereas, in perfect competition, no buyer or seller decides the price as it is the market forces of supply and demand that decides the price, individual players are price takers (figure). Market supply and demand are determined by the aggregate of individual producer/service provider and consumer (figure).

Table 1 characteristics of different types of market structure; source-The Economics of Food and Agricultural Markets, 2019

Perfect Competition	Monopolistic Competition	Oligopoly	Monopoly
Homogeneous good	Differentiated good	Differentiated good	One good
Numerous firms	Many firms	Few firms	One firm
Free entry and exit	Free entry and exit	Barriers to entry	No entry

Figure 6 Determining prices



Price determined in a perfectly competitive market maximizes welfare of the society as it discovers the right price that optimally allocates resources to match the demand and supply and there is no deadweight loss. Market structures other than competitive markets, allow buyers or sellers to determine the price and therefore leads to welfare loss to the society. The monopoly's deadweight loss is depicted in the diagram below. Under monopoly, producers produce the quantity such that marginal revenue and marginal cost are equal. Deadweight loss is incurred when total output produced is less than at socially optimal level. Such losses are high if the market structure is monopoly, and the demand is elastic.

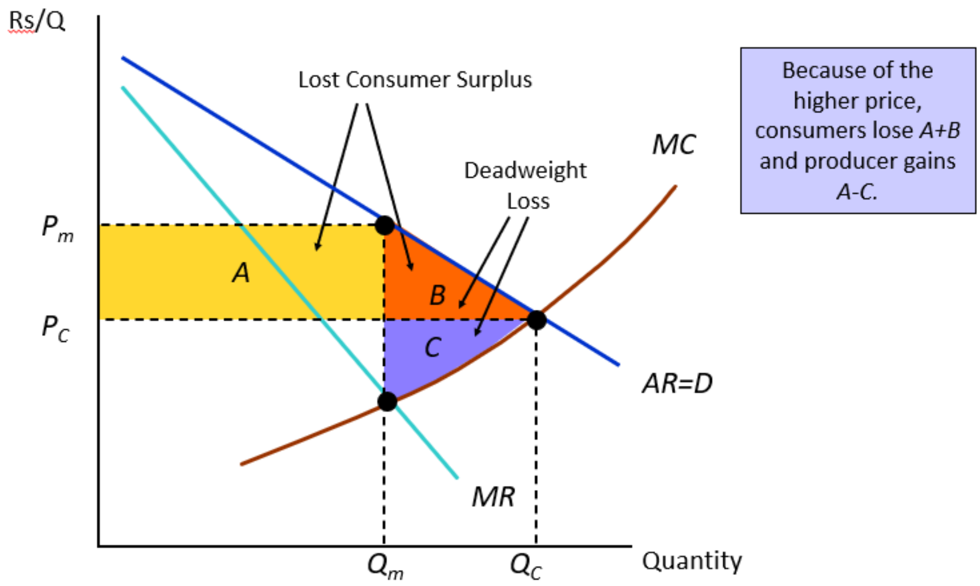
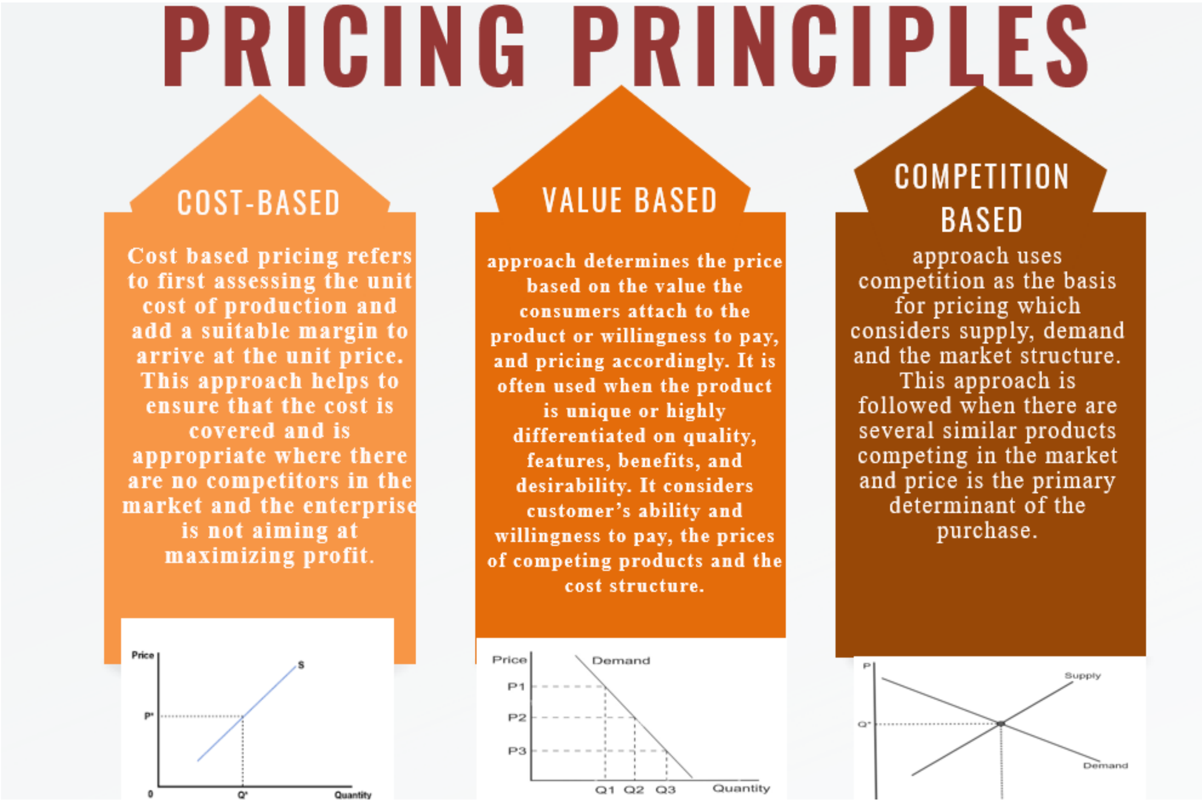


Figure 7 Deadweight loss

In case of public utility service like water, the market structure is likely to be monopoly, and the demand inelastic creating potential for high welfare loss if left to market forces to determine prices. Such situation generally demands price regulations to enhance welfare of the society. Therefore, there is a need to think about what a competitive price should be, in order to maximize welfare and eliminate deadweight loss. In such situation, prices can be determined considering the market forces for fairness and to maximize social welfare. Also, marginal social cost, the costs incurred by others due to production of one unit (negative externalities), and marginal social benefit, the benefit accrued to others due to one more unit of production (positive externalities), need to be considered while deciding the price.

Pricing Principles

There are three types of pricing principles that one can consider for piped drinking water delivery system.



Value based pricing is inappropriate as it leads to higher price than the other two methods. In case of competitive pricing unless market structure allows, the method is not suitable. Therefore, a practical approach in the case of drinking water supply seems to be cost based approach.

Tariff Mechanism

The true cost of producing, treating, and distributing water can be the basis for setting the tariff. The cost-based tariff mechanism can be broadly classified as

- Flat Pricing and
- Volumetric Pricing

A suitable approach to water pricing depends on various factors such as geography, socio-demographic background, existing water sources etc. or simply administrative ease.

Flat Pricing Approach

In a flat price approach, the service provider charges the same amount tariff for a particular product or service, usually in competition with a volume-based pricing strategy. In the case of piped water supply, a fixed monthly charge per household is a flat pricing strategy. While this approach is simpler to implement, it may not be a fair pricing system where there are large variations in the sizes of the households and where water is scarce. The strategy does not promote judicious use of water.

Figure 8 Flat pricing

Volumetric Tariffs

Under volumetric tariffs, water charges are directly proportional to the water consumption. Hence, higher consumption will result in higher water charges. Increasing block tariff, uniform water tariff and two-part tariffs are volumetric tariffs.

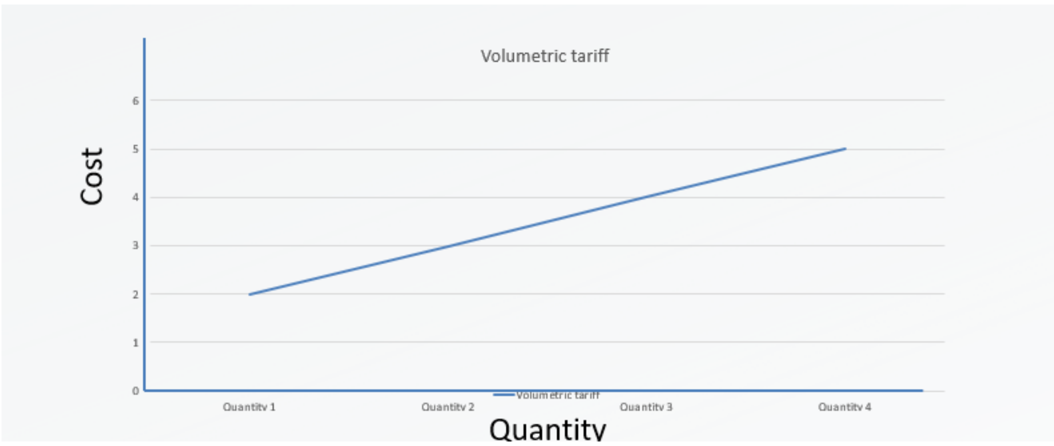
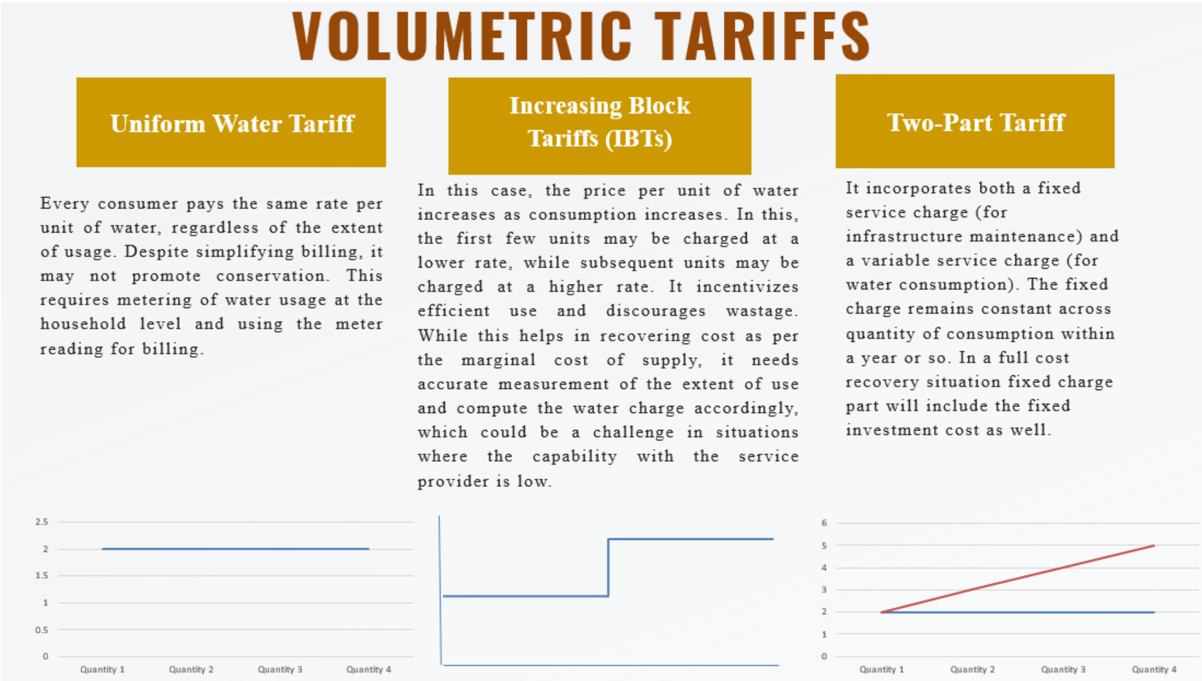


Figure 9 volumetric tariff

There are three different types of volumetric tariffs:



Advocating for cost-based pricing strategies:

Cost-based pricing strategy is the best suitable approach for an essential product like piped drinking water system delivery since it promotes welfare maximization and also covers the cost of delivering piped drinking water.

Illustration of the relationship between costs and demand

Demand	Fixed Cost	TVC	Total cost	Av var Cost	Av Total Cost	Marginal Cost	Price	MR
1810.4	157248	42661.83	199909.8	23.56	110.42		190	
3620.8	157248	61143.06	218391.1	16.89	60.32	10.21	140	90
5431.2	157248	79624.29	236872.3	14.66	43.61	10.21	100	20
7241.6	157248	98105.52	255353.5	13.55	35.26	10.21	70	-20
9957.2	157248	125827.4	283075.4	12.64	28.43	10.21	28	-84
10862.4	157248	135068	292316	12.43	26.91	10.21	16	-116

Figure 10 Relationship between costs and demand

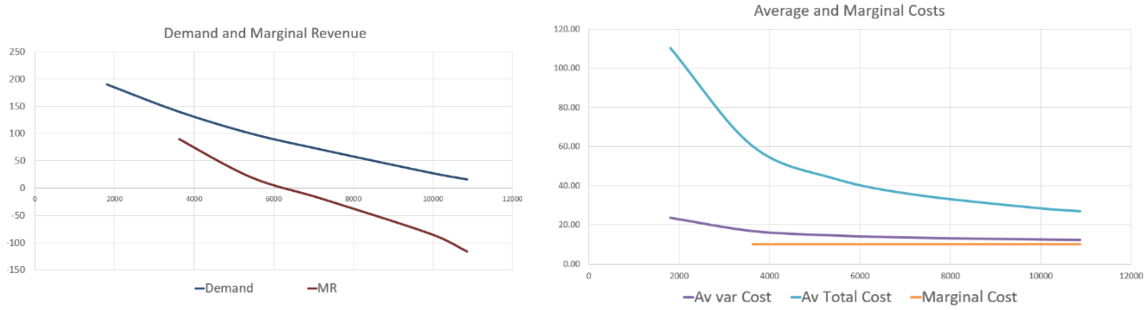


Figure 11 Relationship between demand and MR, AC MC

Figure 12 Price determination based on Average total cost and Average variable cost

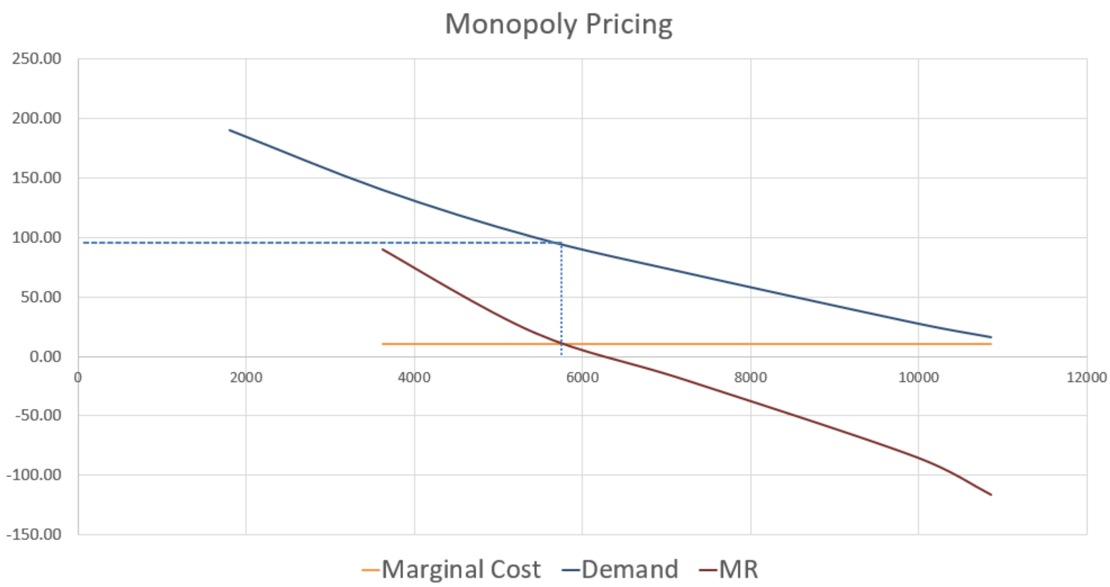


Figure 13 Monopoly pricing

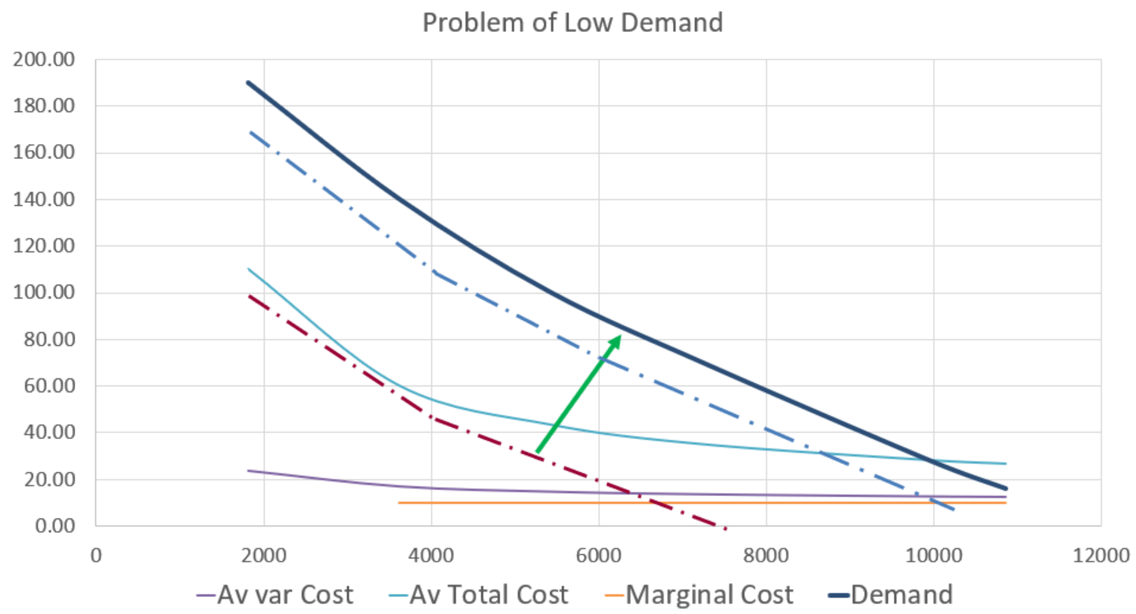
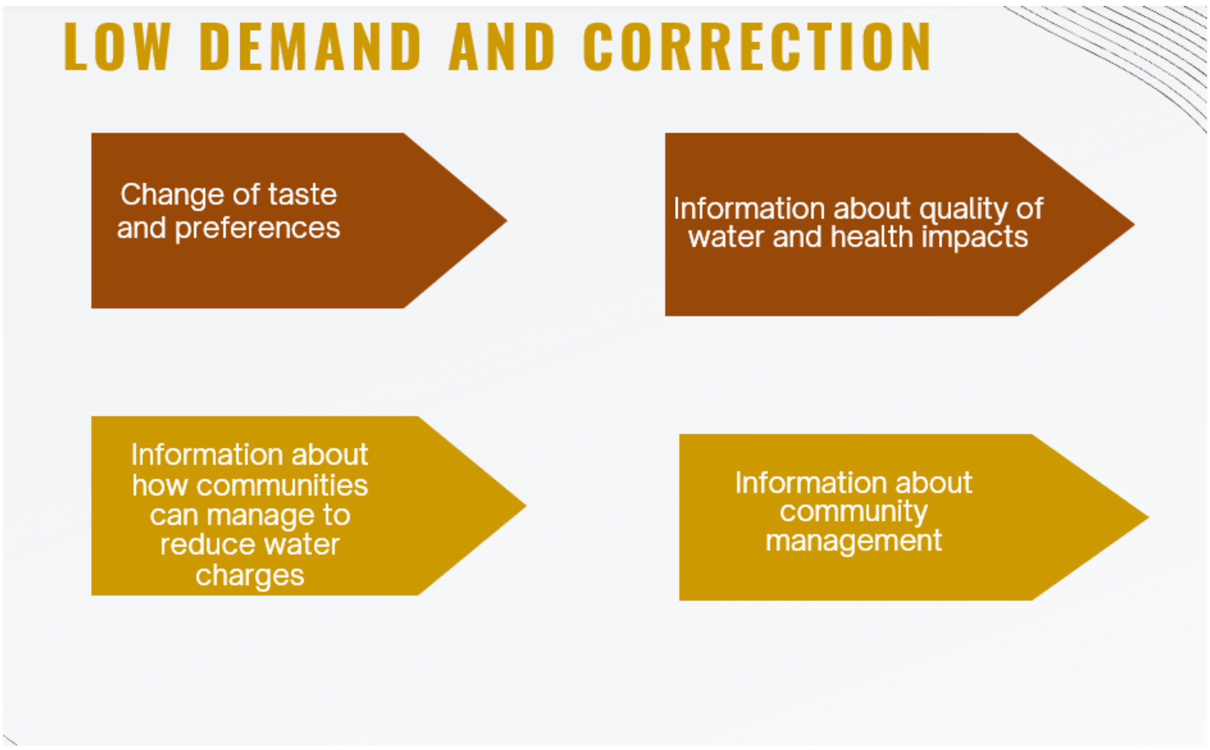


Figure 14 problem of low demand



Costing

Though, the full cost recovery helps in ensuring timely repair and maintenance as well as replacement, at the very least, in the initial stages, such projects envisage covering operations and maintenance expenses. Unit cost of service delivery is an important metric in effective management of any system. The unit costs and its components need to be computed periodically as a performance measure as well as to help in determining water charges. Such cost computation helps in understanding the cost structure so that comparisons can be made across schemes and overtime to understand areas of strengths and weaknesses and help to take appropriate measures. Full cost computation needs to be done even if the immediate objective is to cover only operational costs through user charges as it helps in understanding the total cost of service delivery and plan for meeting replacement expenses well ahead of time so that the burden of lumpsum expenses can be avoided.

Demand for piped drinking water

Demand for piped water systems depends on availability of alternative sources of water and seasonality and perception of quality of water and perception about quality, quantity, regularity, and prices of piped water. JJM prescribes a minimum supply of 55 liters per capita per day of standard quality. It is also important to understand how perception plays an important role in determining the demand for piped drinking water. Water quality and water availability can play a pivotal role in determining the demand. There are four scenarios that can be arrive from the way people perceive water quality along with water availability.

WATER SCARCITY

WATER QUALITY

Quality of Available	PERCEPTION ABOUT QUALITY OF AVAILABLE WATER	Water availability: Abundant all seasons	Water availability: Seasonal scarcity	Water Availability: Scarce through out the year
Good	Perceived Good	Low demand	Seasonal Demand	High demand
	Not perceived Good	Medium demand	High demand	High demand
Bad	Perceived Bad	Medium demand	High demand	High demand
	Not perceived Bad	Low demand	Seasonal demand	High demand

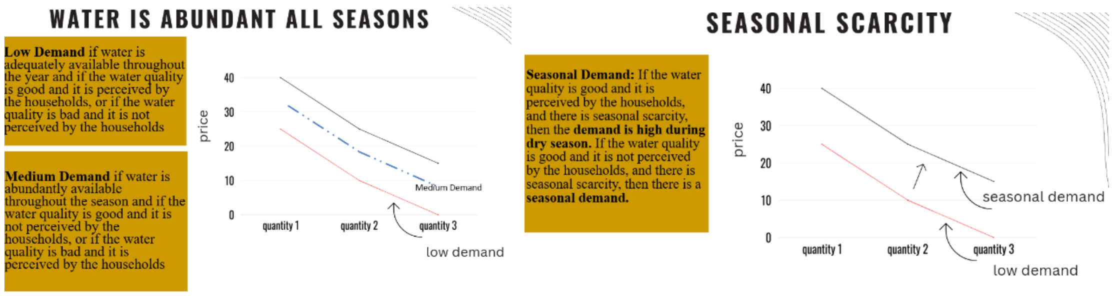


Figure 15 Scenarios when water is abundant all season and water is seasonally scarce

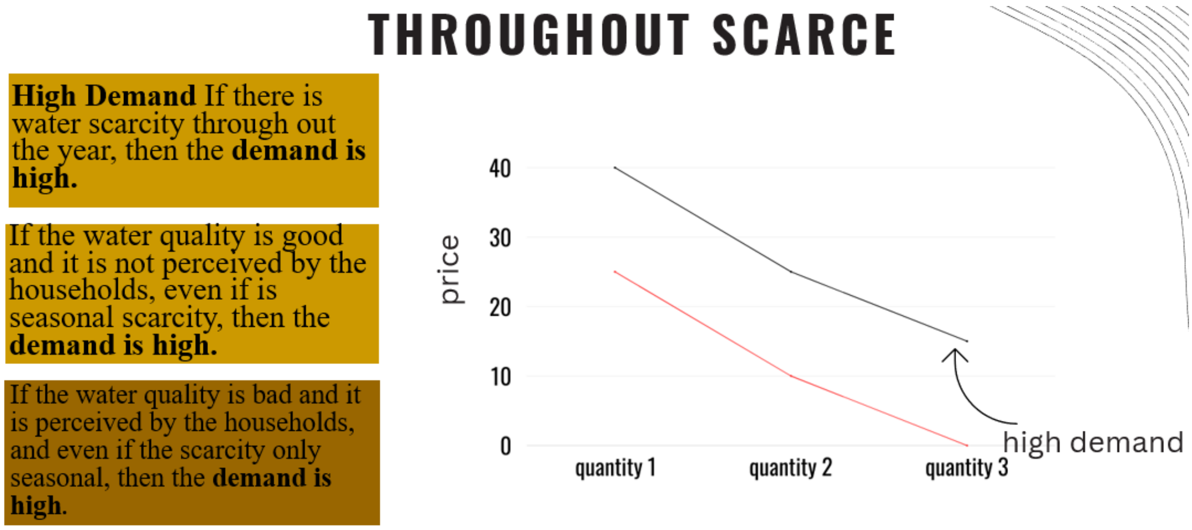


Figure 16 Different scenarios when water is throughout scarce

Social costs and social benefits

Social costs included both the private and the costs of externalities. Private costs are the costs facing individual decision-makers based on actual market prices (B. Metz, 2007). The prices are derived from market prices, where social costs and benefits are considered.

It is important to take into consideration the social costs of providing functional household tap connections to every household. The social costs that can be considered are:

- The cost of extracting water.
- Cost of electricity and distribution.
- Possibility of contamination of water.

Social benefits refer to the returns that society gets for incurring social costs. In this case the social benefits could be:

- Grey water management.
- Providing good quality drinking water and functional household tap connections to every household.
- Improving the general health of the public by providing adequate water supply.
- Incorporating good practices to judiciously use water sources.
- Training the community to manage and operate the water treatment plant.

Social returns should be maximized while social costs should be minimized in order to promote the well-being of all members of society. Market outcomes can lead to underproduction or overproduction in terms of a society's overall condition unless all costs and benefits are internalized by households and firms making purchasing and production decisions (what economists call the "welfare perspective") (B. Metz, 2007).

Management of costs and Revenue

Types of Cost

Providing large public infrastructure projects, like JJM, are often implemented with the understanding that costs are recovered through the benefits that accrues directly or indirectly to individuals and community. Though, the full cost recovery helps in ensuring timely repair and maintenance as well as replacement, at the very least, in the initial stages, such projects envisage covering operations and maintenance expenses.

Unit cost of service delivery is an important metric in effective management of any system. The unit costs and its components need to be computed periodically as a performance measure as well as to help in determining water charges. Such cost computation helps in understanding the cost structure so that comparisons can be made across schemes and overtime to understand areas of strengths and weaknesses and help to take appropriate measures. Full cost computation needs to be done even if the immediate objective is to cover only operational costs through user charges as it helps in understanding the total cost of service delivery and plan for meeting replacement expenses well ahead of time so that the burden of lumpsum expenses can be avoided.

The costs involved in establishing and operating a project like drinking water are mainly of two types: Capitalized cost or fixed cost and the other is operation and maintenance expenditure.

1. Capitalized Costs

   Capitalized costs are incurred when building or purchasing fixed assets of a long-term nature such as construction of tubewell/Jackwell, pump, over-head tank, pipeline, etc. These costs are recognized over time via depreciation or amortization. Capitalizing costs aligns with the matching principle, ensuring expenses match the periods in which the asset generates revenue.

2. Operating Expenses

   Operating expenses are the regular, ongoing costs incurred to maintain its day-to-day operations which includes the cost of running the infrastructural set-up. These expenses are recurring and occur frequently such as salaries and wages, electricity, etc. Operating expenses are essential for continuous functioning and are immediately expensed.

It is important to understand the full cost of servicing water delivery to examine the component of costs and how to recover them. For this purpose, the capitalized cost needs to be computed of each year to combine it with the operations and maintenance cost to arrive at the full cost. While depreciation and amortization are two methods of arriving annualized fixed cost, for our purpose the appropriate method is amortization. Depreciation alone cannot take care of full fixed as it only accounts for the book value of the capital cost. Along with the capital cost, there is opportunity cost, the return from a next best alternative investment, that needs to be included, and hence amortized amount is taken as the fixed cost. This approach also helps in taking care of inflation in prices of assets at the time of their replacement.

Linear model for total cost

The total cost can be represented as a linear regression model where fixed cost is the intercept component and Operational and maintenance cost is a variable component depended on the extent of water supply.

Linear regression models are used to derive causal relationship between the dependent variable and the independent variable. In this case, total cost is the dependent variable, which is dependent on the units of consumption. The model can be described in the following way:

$$Y_i = \beta_0 + \beta_1 X_i$$

where Y_i = Dependent variable,

β_0 = constant/Intercept, the fixed cost

β_1 = Slope, increase in cost per unit of water used

X_i = Independent variable, the quantity of water used

Based on the linear modelling, it can be graphically represented in the following manner:

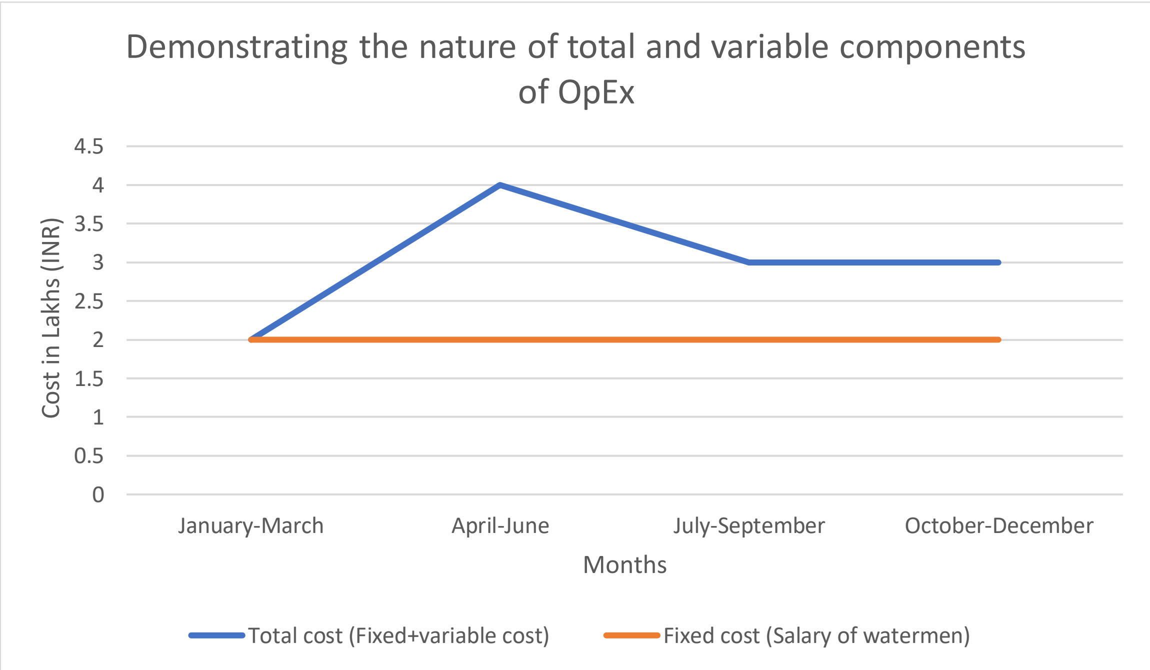
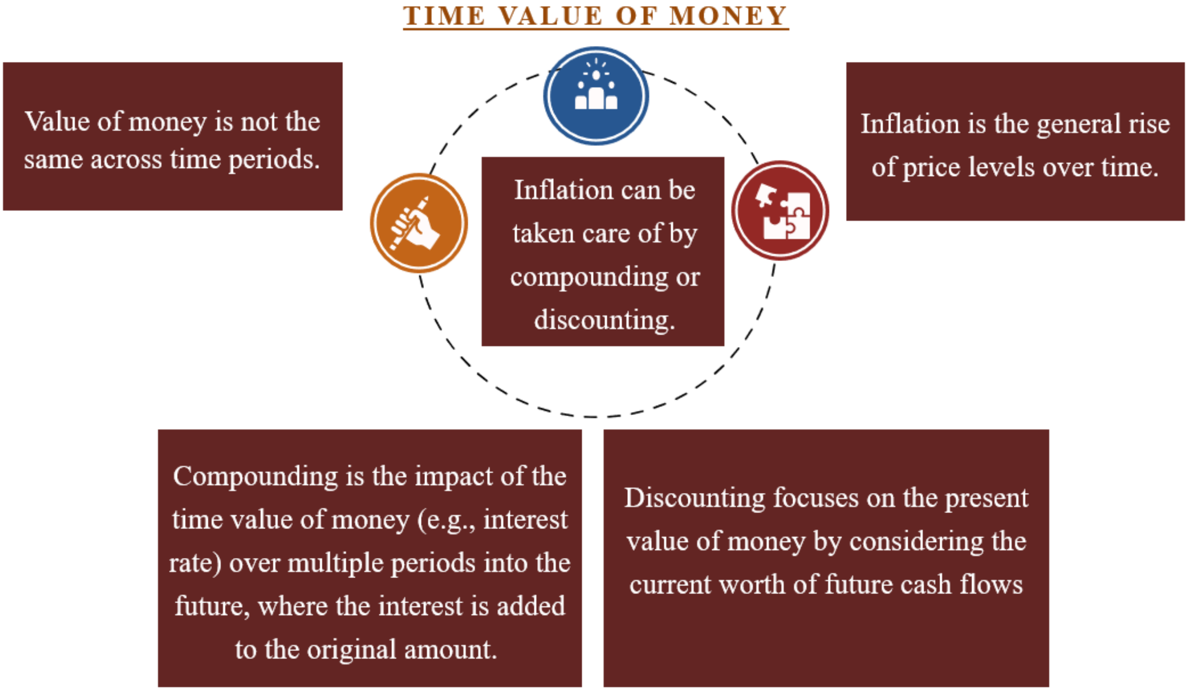


Figure 17 The nature of total and variable components of OpEx

The total cost consists of the fixed cost and the variable costs. The variable cost peaks during the summer season and then diminishes gradually during the winter season. It is important to note that the graph does not start from the origin of the axis highlighting that there always will be a fixed cost, in this case the salary of the watermen even though theoretically electricity charges can be 0, however salary must be paid and hence this fixed cost will be incurred even if no water is being pumped for consumption.

Time value of money



Amortization while calculating costs

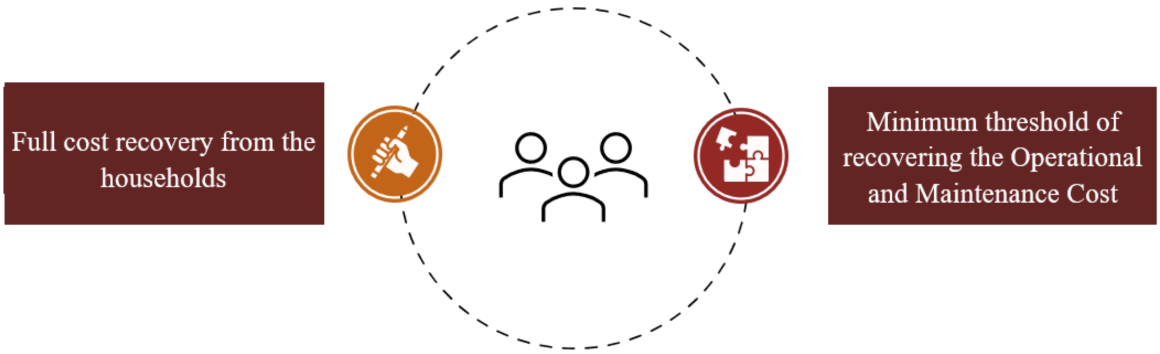
Cost calculation requires taking into account the various one-time expenditure as well as recurring expenditures. The infrastructure for delivering water to the villages are built to sustain and cater the needs of the future population as well. It is important to incorporate the opportunity cost for the infrastructure to understand the value of the water delivery system. To do so inflation rates are incorporated while calculating the annualized cost. The annualized fixed cost is computed by computing the annual ammortization at an interest or inflation rate. The annual amortization is necessary to calculate to incorporate the opportunity cost or in other words the next best alternative that could have been utilized, if this amount was invested in some other place. Also, ammortization helps to incorporate the inflation rate the future rise in price level.

Formula for calculating average annual fixed cost is-

$$E = P \cdot r \cdot \frac{(1+r)^n}{((1+r)^n - 1)}$$

- **E** is Average Cost
- **P** is Investment Amount
- **r** is the rate of interest
- **n** is life tenure of the asset in years

DIFFERENT APPROACHES TO RECOVER COST



How to arrive at unit costs

We can use two different units for computing unit costs.

First, is the per kilo litre of water supplied which helps to implement charging water on volumetric basis. Second, is the per household cost which is a flat rate pricing.

The steps for arriving at unit costs and determining surplus/deficit are as follows:

Step 1: Classify the costs into capital expenditure and operating expenditure. The annual operating costs is sum of all operating and maintenance cost incurred in a year.

Step 2: Calculating the annualized fixed cost. The annualized fixed cost is obtained by computing the annual amortization at a risk-free interest rate.

Step 3: Calculating the annual total cost.

Annual Total Cost = Annual Fixed Cost + Annual Operating Cost.

Step 4: Calculating the annual total cost per kl.

Annual Total Cost per kl = Annual Total Cost/ Estimated Annual Supply of Water in kl

Step 5: Calculating the annual total operating cost per kl

Annual Operating Cost per kl = Annual Operating Cost/ Estimated Annual Supply of Water in kl

Step 6: Calculating the annual total cost per household.

Annual Total Cost per HH = Annual Total Cost/ Total number of HH served

Step 7: Calculating the annual operating cost per household.

Annual Operating Cost per HH = Annual Operating Cost/ Total number of HH served

Step 8: Fixed cost per kl and per household can be obtained by subtracting operating cost from total cost. Monthly average total, fixed and operating costs can be calculated by dividing the annual total cost, annual fixed cost and annual operating costs, respectively, by 12.

Accounting other revenue while computing tariff

While determining tariff for households, other possible revenues sources need to be taken into account. These sources could be interest on corpus fund created by the VWSC, Government Grant, etc. These annual sources of funds if available to the VWSC needs to be ascertained and deducted from total cost before arriving at unit cost on either a flat rate or volumetric basis. This needs specific Government policy to be in place.

Identifying the barriers causing low demand of piped water delivery system using the barrier identification tool designed by Behavioural Insights Team UK.

Key determinants of financial sustainability are whether households are getting water as promised in the guidelines in terms of quality, quantity and reliability; whether households are satisfied with the water and they use it for all domestic purposes; and whether they are paying water charges. The use and pay for water by the households also depend on their beliefs and attitude towards tap water connection and may act as barriers.

In many cases there is low demand due to perception and beliefs about tap water connections due to which households refrain from using FHTC. Specific barriers can be identified through the barrier identification tool designed by the Behavioural Insights Team UK.

Below is a sample identification of barriers using the barrier identification tool (Barrier Identification Tool, 2019) where the barriers are categorized into Capabilities, Opportunities and Motivations using the COM-B model. In this case the higher goal is to encourage households to consume the water provided through FHTC and encourage them to pay the water charges in a timely manner. To implement this higher goal the following barriers were identified:

Your Report

During this activity you identified your problem, high level goal and the specific behaviour you are trying to change. You can see these below.

Problem:	Households are reluctant to consume the water supplied through functional household tap connections
High Level Goal:	To encourage individuals to consume functional household tap connection water and pay monthly water charges
Behaviour to change:	Reluctance to use water supplied through FHTC

Capabilities: These refer to a person's physical or psychological ability to perform a behaviour. There are five barriers under capabilities which are cognitive skills, interpersonal skills, attention span, memory, and awareness.

- Cognitive skills refer to the technical understanding of the desired behaviour (in this case switching to the consumption of water supplied through FHTC). It is important to ensure that individuals should attain the technical capability to understand the importance of consumption of treated water supplied through FHTC. Specifically, the understanding of good/ standard quality of drinking water and the importance it has on the health of the individuals.

- Interpersonal skills refer to the ability to communicate with other individuals in the community. In this case it is important to ensure that the community has the necessary interpersonal skills to communicate with the authorities to address the issues regarding the treated water supplied through FHTC.
- Attention span refers to the level of concentration required to absorb information. In this scenario, if individuals are being briefed with technical jargons, there can be a possibility that they will not have a long attention span to absorb and understand the information and hence they would probably still hesitate to consume water from FHTC.
- Memory refers to the ability to recall the information provided after a short or long term. In this case, individuals may forget after learning about the importance of clean drinking water and may go back to their traditional sources of drinking water. To ensure that they can recall the benefits of FHTC, information saliency is needed.
- Awareness refers to the ability of the individuals to be conscious of the alternative sources of water available to them. It should be ensured that individuals are made aware of the uses and benefits of FHTC, and they do not feel that there is no alternative to their traditional sources of drinking water.

Figure 18 Capabilities from the COM-B model; Source: BIT

Opportunities: Refer to anything in the physical environment that encourages or discourage a particular behaviour. In this case, opportunities can be:

- Prompts in the environment which refer to incentivizing to encourage a behaviour or disincentivizing to discourage a particular behaviour. In this case, the prompts in the environment can be providing information about the total investment and the infrastructure developed to ensure adequate, secure and safe drinking water and the capacity building measures available.

- Role Models refer to an ideal person which the individuals look up to. If the role models start practicing a behaviour, it is possible that will encourage the entire community to behave in that way. In this case, if the individuals look up to the village Sarpanch or head and if he/she consumes FHTC water, then it is possible that the whole community embraces that practice.
- Social and Cultural norms refer to the rules or the expected behaviour of the individuals residing in the community. In this case, if there is a social norm of consuming water from traditional sources of drinking water then, it is required to introduce an intervention which can help deconstruct the norm and create a new social norm by encouraging individuals to drink clean drinking water from FHTC. Households needs to be convinced that this water is fit for worship as well.

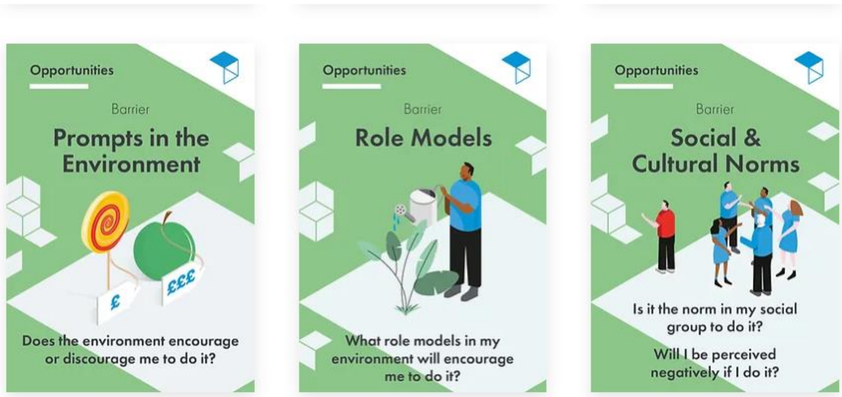


Figure 19 Opportunities from the COM-B model; Source: BIT

Motivation: These refer to internal reflective and automatic mechanisms that activate or inhibit a behaviour. The motivations identified are:

- Identity refers to aligning the behaviour with one’s identity. In other words, if an individual perceives that activating a behaviour goes against his/her identity; then there is a possibility that the individual will refrain from behaving in that manner. In this case, if drinking water from the tap makes individuals believe that it is not conventional for them to drink water from the taps and it is creating a separate version of themselves compared to their ancestors who used traditional sources of drinking water, then it is important to make them realize that drinking water from the tap connections is not compromising their traditional identity.
- Beliefs about consequences refer to the thought process of individuals regarding the consequences of their actions. Individuals might think that drinking water from the taps can alienate them from the rest of the community members and this behaviour will be perceived as a deviation from the expected behaviour of consuming water from

traditional sources. Under such circumstances, they might refrain from consuming water from FHTC and continue using traditional sources of water.

- Habits refer to the usual way of behaving in a certain way. If individuals have the habit of consuming water from the traditional sources, then shifting to FHTC may seem difficult or even impossible for them since they would be accustomed to the activity of getting the daily water from sources like river and the taste and odour of the FHTC water may seem different, hence would reduce the satiation of thirst.
- Accountability refers to the act of showing responsibility. In this case if individuals are using water judiciously or not, there is no way to monitor that without the proper functioning of water meters. Also, monitoring the payment of water charges by them needs to be regularized which can be an act of accountability.
- Automatic responses refer to pre-determined responses which are triggered by a specific event. In this case if individuals get very thirsty while travelling and they can find a traditional source of water, it is possible that automatically they would drink water from there rather than finding a FHTC household for water consumption.

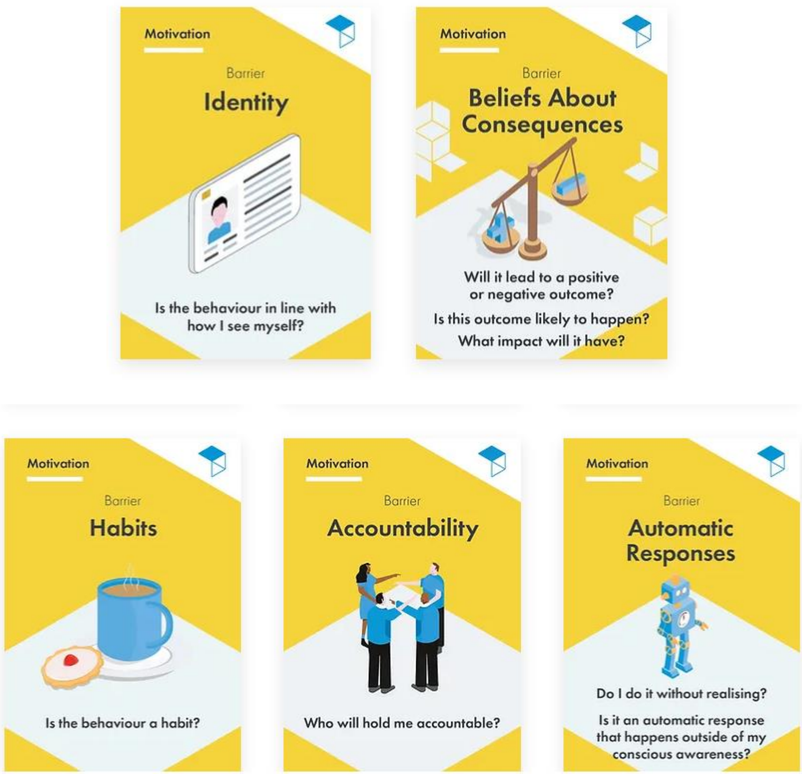


Figure 20 Motivation from COM-B Model; Source: BIT

These barriers can be encountered in multiple ways such as by using the EAST Framework or by using the behavioural change wheel to change the behaviour among individuals. (Barrier Identification Tool, 2019).

Case study

Illustration of Unit Cost Computation

Jal Jeevan Mission has been implemented through two types of schemes: Multi-village Scheme (MVS) with In-Village Distribution System (IVDS) and Single Village Scheme (SVS). In the case of MVS-IVDS system, the unit cost is computed at MVS level as well at individual IVDS level. While MVS costs are directly relevant to concerned IVDS, the extent of burden depends on the State Government Policy. For example, State Government may have a policy to subsidize full or fixed cost component of MVS from the state budget and not imposed on the beneficiary households to reduce the tariff burden on the households. Here unit cost computation in both the types of schemes is illustrated.

Cost Computation for MVS and IVDS

For MVS and IVDS, the case of Gokarna MVS is used. Under Gokarna MVS there are six GPs - Gokarna, Hiregutti, Bargi, Hanehalli, Nadumaskeri and Torke of Kumta taluk Uttar Karnataka district in Karnataka. These 6 GPs have 19 villages and 9090 houses covered under the scheme.

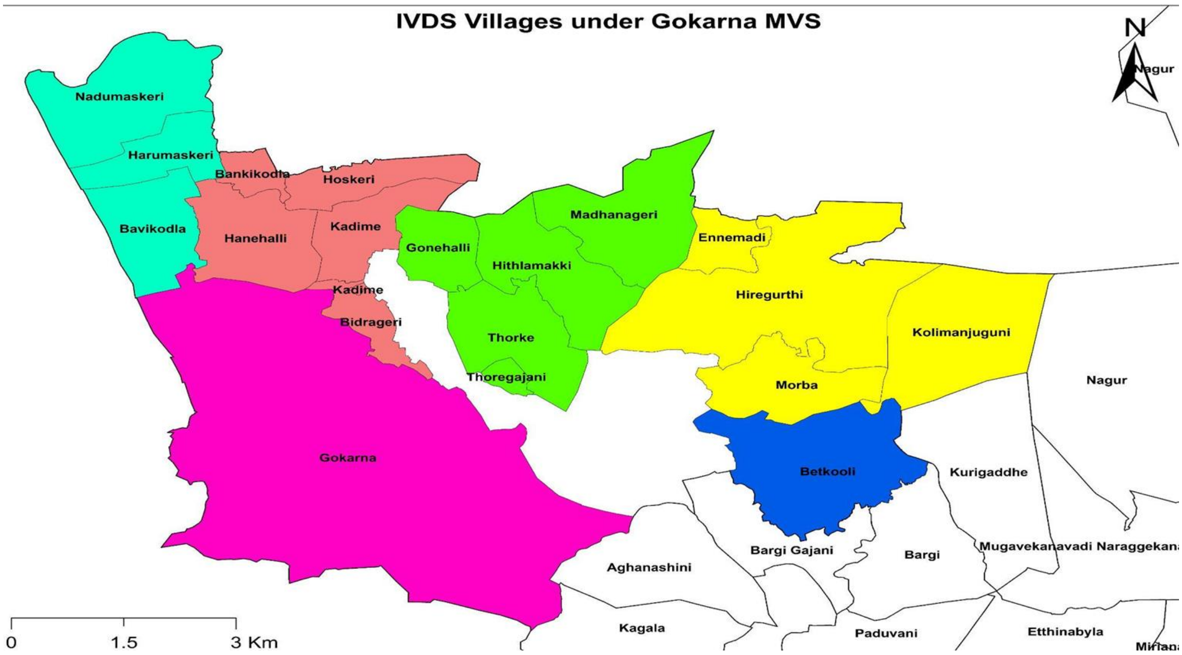


Figure 21 Location of the IVDS in Gokarna

As a first step, the cost items are categorized as fixed cost items and operation and maintenance cost items. The fixed costs include the cost of infrastructure set-up provided by JJM that include the cost of headworks, pumps, pipeline works, distribution and the cost of express feeder line. The expenditure on these items is summed up to obtain total investment cost. The annualized fixed cost is then computed using the investment cost and the designed life of fixed infrastructure in years and risk-free interest of 6%. If the designed life is different for different assets, the annualized cost is separately worked out and added together to get the total annual fixed cost. The interest rate included compensates for the price inflation of the capital assets at the time replacement. Dividing the annual fixed cost by 12 gives us the monthly fixed cost (Table 1).

The operations and maintenance cost for MVS includes - establishment charges, electricity charges, maintenance cost of civil works, maintenance cost of electro-mechanical components, expenses on consumables, transportation and communication charges, office accommodation charges, cost of water quality testing, water generation and stationery charges. The operations and maintenance cost for IVDS includes- temporary and permanent waterman salaries and repair and maintenance costs, power charges, if any (Table 2).

The monthly total cost is calculated by adding the monthly fixed cost and monthly operation and maintenance cost or by dividing the annual total cost by 12.

Table 1 Annual Fixed of Gokarn MVS

Sl. No.	Particulars	Amount in INR
Part-A		
1.	Component-1 Head works, WTP, Raw water & Pure water rising mains, Feeder mains, Pure water sump, Master balancing tank, Pump, GLSR/Sump, houses/Control Rooms, D I Unit rooms all civil components	71,090,447.85
2.	Component-2 Pipeline work	153,294,867.88
3.	Component-3 Mechanical and Electrical Works Viz. Pumping Machinery/Valves/Chlorinating unit etc.,	29,045,784.87
4.	Componenent-4 Express Feeder Line, Transformer, and another component	35,118,307.49
5.	Component-5 Distribution cost	18,65,00,000.00
6.	Total Fixed Cost	47,50,49,408.09
Part-B		
1.	Design Life of Fixed Infrastructure in (Years) (Number)	25
Part-C		
1.	Investment cost per annum (Part A/B)	1,90,01,976
2.	Annual Fixed Cost	3,71,61,556
3.	Monthly Fixed Cost	30,96,796

Table 2. Annual Operations and Maintenance Cost of Gokarn MVS

Sl. No.	Particulars	Amount in INR
Part-D		
1.	Establishment charges	3050087.04
2.	Electricity Charges	7501599.46
3.	Maintenance of Civil Works	177726.12
4.	Maintenance of Electro-mechanical components	1604102.31
5.	Consumables	355511.83
6.	Transportation and communication charges	265200
7.	Office accommodation charges	60000
8.	Cost of water quality testing, Report generation & other Stationery	60000
Part-E		
1.	Annual operations and maintenance cost (Total of Part-D)	**1,30,74,227**
2	Monthly operations and maintenance cost (INR)	**1089519**
Part-F		
1.	Annual Total Cost (Fixed Cost + Operations and Maintenance Cost) (	**5,02,35,783**
	Monthly Total Cost	**41,86,315**

The operational cost per kl is determined by dividing the annual operational cost by the annual demand for water in kl (Table 3). Similarly, the total cost per kl can be determined by dividing the annual total cost by the annual demand for water in kl. While computing volumetric unit cost, if we are using total water supply, we need to keep in mind to deduct non-revenue water.

The annual total cost per household is determined by dividing the annual total cost by the number of households. Similarly, the annual operating cost per household is determined by dividing the annual operating cost by the number of households. The monthly total cost and operating cost per household can be calculated by dividing the annual total and operating cost by 12. Finally, the annual total cost is deducted from the amount of total water charges levied per year for the total number of households which reflects whether there is a surplus or deficit over total annual cost. Similarly, the total annual operating cost is deducted from the amount of total water charges levied per year for total number of households which reflects whether there is a surplus or deficit over total annual operating cost.

Table 3. Unit Costs Computations for Gokarna MVS

Sl. No.	Particulars	Quantity
	Part-G	
a.	Present Total Population (	51,277
b.	Design Total Population	52,129
c.	Per capita rate of water supply (ltr)	5
d.	Daily Demand of Water Habitation (ltr)	5,230,254
	Annual Demand of Water (d*365) in ltr	1,909,042,710
	Part-H	
1.	Operational cost of water delivery for 1kl in (INR) [(Part-E(1)/G) *1000]	6.85
1.	Current annual demand of water in kl	1,909,042.71
	Total cost per kl (INR)	26.31
3.	Share of operation cost in total cost (%)	26.03
	Total number of households (9090)	Amount
1.	Annual operational cost per HH (INR)	1438.31
2.	Annual Total cost per HH (INR)	5526.49
3.	Total monthly cost per HH (INR)	460.54
	Monthly operational cost per HH (INR)	119.86
	Calculation of Surplus or Deficit over Opex & Total cost	Amount
1.	Water charges levied per HH per month (INR)	90
2.	Total water charges levied per year for all the 9090 households (INR)	9,817,200
3.	Surplus/Deficit over operational cost (INR)	-3,257,027
4.	Surplus/Deficit over Total cost (INR)	-39,986,027

Currently the operations cost of IVDS is mainly salary of water person in Gokarn MVS. The water from MVS flows to OHT in the villages through gravitational force and therefore no additional power is required. As the system is new there is no repair and maintenance cost as of now. The salary paid for water persons in the 3 Gram Panchayats is presented in table 4.

Table 2 Operating cost for IVDS

Village	Component	Amount INR
Torke	1 waterman permanent	15000/month
	2 temporary watermen (March-June)	6000/ month/ waterman
Hoskeri	1 permanent waterman	15000/ month
	2 temporary watermen (March-June)	5000/month/ per waterman
Gokarn	3 permanent watermen	16000/ month
	1 temporary watermen (whole year)	10000/month

Based on the above information the monthly operational cost per HH for 3 habitations in the 3 GPs is shown in table 5. In the table the MVS monthly operational cost and total costs are presented from table 3 which are added with the monthly operational cost of IVDS to obtain IVDS monthly total operational cost and monthly total costs.

Table 3 Operations and Total cost per HH for IVDS

S.No.	Particulars	Gokarn	Hoskeri	Madanageri
1	Monthly IVDS operational cost per HH (INR)	17.87	13.98	25.74
2	Monthly MVS operational cost per HH (INR)	119.86	119.86	119.86
3	Monthly MVS total cost per HH (INR)	460.54	460.54	460.54
4	Monthly IVDS total operational Cost per HH (INR)	137.73	133.84	145.6
5	Monthly IVDS total cost per HH (INR)	478.41	474.52	486.28
6.	Water charges levied per HH per month (INR)	100	Not yet charged	80
7	Monthly charges needed to cover operational cost	137.73	133.84	145.6

Cost Computation for SVS

Cost Computation for SVS is simpler as it deals with only one system. Here we take an example of SVS in Odisha, Kamapalli habitation in Ganjam District.

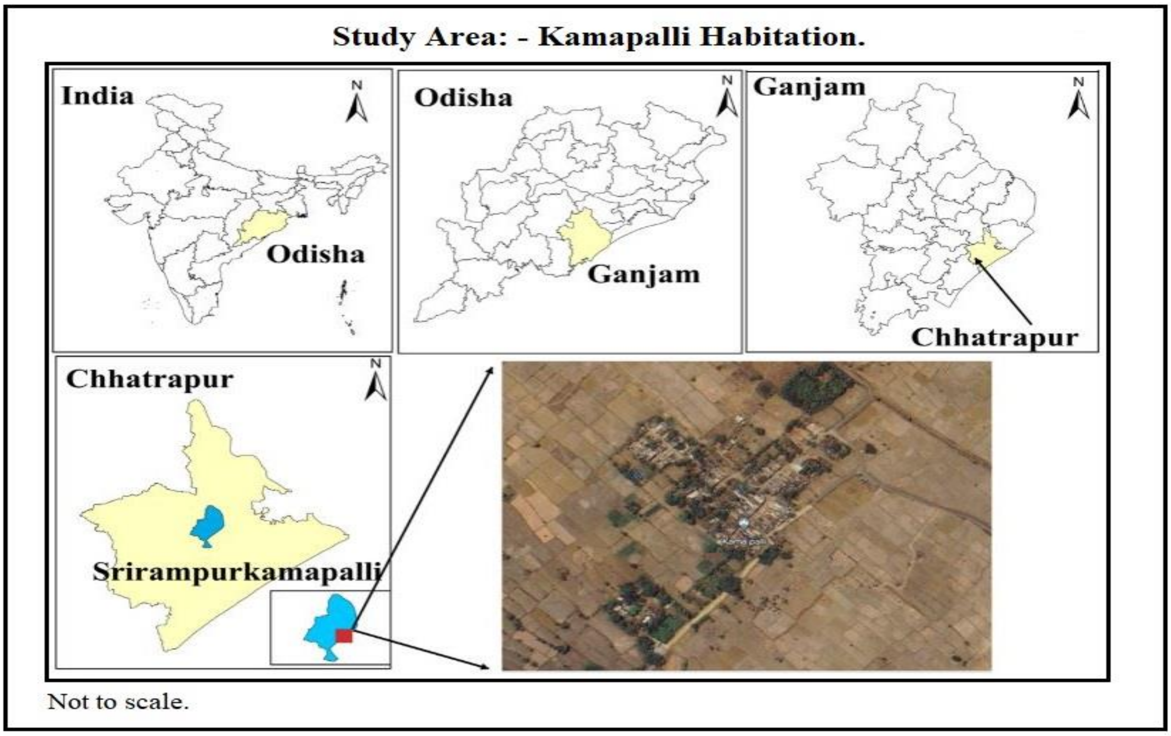


Figure 22 Location of Kamapalli habitation

Cost of Infrastructure and operations

The Kamapalli habitation's total cost of water supply infrastructure was INR 14,76,136 that catered water to 103 households, indicating that the average investment per household is INR 14,331. The designed life span of this infrastructure being 25 years. Considering an opportunity cost at @6% on the investment, the total annualised cost is INR 1,14,696. In this system, a major operational cost is electricity charges, as one of the pumps is an electric pump operated daily. A solar pump is also installed at the second tube well, but it hasn't incurred any maintenance cost till date. Assuming the maintenance cost will be 0.5% of the fixed cost, the annual maintenance cost works out to be INR 7,380. Currently, the water charges collected is INR 5.50 per kl, volumetric pricing, for consumption of <5 kl, which has been decided unanimously by the community.

Based on the total fixed cost, operational cost, and annual water demand for an estimated future population of 857, the actual cost per kl of water works out to be INR 7.18 (**Table 6**), which is more than the current water charge of INR 5.50 per kl. If we consider the current actual population of 496, the fixed cost works out to be INR 9.05 per kl, while the operational expense is INR 3.36 per kl. The total cost then amounts to INR 12.41 per kl (**Table 7**). If the VWSC decides to have ownership of the infrastructure and its upgradation during the end of the current design period, then the revision of monthly charges needs to consider recovery of the total cost of INR 12.41 per kl.

For an average household of this habitation consuming about 7.7kl of water per month will have to pay INR 95. While it may not be feasible to suddenly increase the water charges to full cost basis, it can be done gradually, starting with say INR 7.5 per kl and so on.

Table 6. Kamapalli Water Delivery Cost

S.No	Particulars	Values in INR
	Part-A	
1	Component-1 (Headworks) [1]	6,81,016
2	Component-2 (Cost of Pipes and Fittings)	1,73,860
3	Component-3 (Distribution System)	1,71,260
4	Component-4 (Solar pump and System)	4,50,000
	Total Fixed Cost	14,76,136
	Part-B	
1	Design Life of Fixed Infrastructure in (Years)	25
	Part-C	
1	Annual Investment cost (Part-A/B)	59,045
	Part-D	
1	Monthly Waterman Salary	1,400
2	Monthly Electricity Charges	1,531
3	Monthly maintenance (@0.5% of the Fixed Cost)	615.05
	Part-E	
1	Monthly Operations & Maintenance cost	3546.05
2	Montly Fixed cost @6% (₹)	9558
3	Monthly Total Cost	13104.05
	Part-F	
1	Annual Total Cost (Part-E*12)	1,57,248.6
2	Annual Operations & Maintenance expenses	42552.6
	Part-G	
a	Present Total Population	496
b	Design Total Population	857
c	Per capita Rate of Water Supply (ltr)	70
d	Daily Demand of Water of Habitation (ltr) (b*c)	59,990
	Annual Demand of Water (ltr) (d*365)	2,18,96,350
	Part-H	
	Total cost of Water delivery for 1kl [(Part-F(1)/G) *1000]	7.18
	Operational cost of Water delivery for 1kl [(Part-F(2)/G) *1000]	1.94

[1] In Kamapalli water delivery cost calculation (Table-3) electricity powered pump cost of ₹28,000/- has been included in Component-1 (Headworks) under section Part-A. Raw data is from Gram Vikas salient features

Table 7. Water Charges as per kl, Flat Charge

S.No	Particulars	Values in INR
1	Current annual demand of water in kl	12672.8
2	Fixed cost per kl	9.05
3	Operational cost per kl	3.36
4	Total cost per kl	12.41
5	Share of Operational cost in total cost (%)	27.05
	Water Charges to be collected	**Amount**
1	Annual Operational cost per HH	413.13
2	Total annual cost per HH	1526.68
3	Total monthly cost per HH	127.22
	Calculation of Surplus or Deficit over Opex & Total cost	**Amount**
1	Water Charge levied per HH per/kl	5.5
2	Total water consumption	8700
3	Total water charges levied per year	47850
4	Total water charges collected per year	47850
5	Surplus/Deficit over Opex (₹)	5297.4
6	Surplus/Deficit over total cost (₹)	-1,09,398

Source: Authors' calculations

Caveats of Cost-based Methods

- In cost-based approach the costs can rise due to various factors such as wastage of water, large amount of non-revenue water, lack of proper operations and maintenance, inefficiency in management of the water supply system, high power cost etc. Under JJM, it has been suggested that water meters should be involved for tracking the consumption pattern of the individuals at the household level. This will help to limit the usage of non-revenue water.
- The infrastructure is designed to sustain for the future population growth also leads to higher present operation and maintenance cost. It is important to emphasize on this matter to figure out how to retrieve this cost without compromising on welfare maximization.
- In many cases there is low demand due to perception and beliefs about tap water connections due to which households refrain from using FHTC. Such barriers can be identified and addresses so that the households attach high value to the FHTC water and increases their willingness to pay water charges.
- It is essential that the households understand the importance of clean drinking water and the concept of FHTC and how that is a step towards development in their village

communities. It is important to understand the barriers that restricts households to pay water charges.

- Water being an essential public good, the water tariff should be fixed bearing in mind the affordability as well along with the recovery of costs. For this purpose, initially focusing on recovering the operational cost can be considered to encourage households to pay and that can be upscaled later to recover the full cost.

Conclusion

JJM advocates for communities/local governments to be involved in the process of implementation and take over the operational and maintenance function of the rural piped drinking water systems. JJM envisages community involvement right from the beginning of the implementation at the time of preparation of village action plan, preparation of detailed project report, infrastructure development and contribute 10 per cent of the investment cost of the project. This contribution and involvement are expected to make the village community take ownership of the assets and manage them efficiently at the construction as well as operation and maintenance stages. To ensure the efficient management of the contribution made by the village community and the daily water charges paid by the households, cost computation is necessary which can reflect the status of financial sustainability at the MVS, IVDS and the SVS level. It is also essential to price the water in such a manner which can maximise welfare and at the same time recover the cost as much as possible. It is important to strike a balance between welfare maximisation and cost recovery.

Key Takeaways

1. **Importance of Financial Management:** Emphasizes the significance of community participation and ownership in managing piped drinking water supply for sustainability.
2. **Cost Recovery:** Highlights the need for determining user charges to ensure financial sustainability and efficient water delivery system.

3. **Pricing Principles:** Discusses cost-based, competition-based, and value-based pricing principles, and their implications on water supply and demand.
4. **Costing Methods:** Provides insights into capital costs, operating expenses, and the importance of understanding the full cost of servicing water delivery.
5. **Unit Cost Computation:** Illustrates practical steps for computing unit costs and emphasizes the relationship between costs and demand.
6. **Costs and Revenue:** Covers the determination of water charges, market structures, and the relationship between marginal revenue, marginal cost, and profit maximization.

Overall, the presentation aims to provide a comprehensive understanding of financial management, cost recovery, pricing principles, and practical illustrations in the context of piped drinking water service delivery organizations.

Policy Directions

Efficient financial management at the VWSC level requires policy direction on the following:

1. Whether states budget support is available for meeting operations and maintenance cost of MVS?

3.Whether state budget support is available for repair and replacement of assets either at MVS level or SVS level?

4.What is the nature of funding support available to SVS on technical assistance needed, training, skill development and capacity building?

5. Whether the State budget will be available for replacement of assets at the end of the life span of those assets. If so, what is the extent of support?

6.Whether state budget support will be available for water quality testing expenses incurred by VWSC?

7.Whether state budget support is available to meet the electricity charges of SVS?

8.Whether state budget support is available to meet the investment on solar pumps

References

B. Metz, O. D. (2007). *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press.

(2019). *Barrier Identification Tool.* The Behavioural Insights Team UK.

Dinar, A., & Subramanian, A. (1998). Policy implications from water pricing experiences in various countries. *Water Policy.*

Economical, Political, and Social Issues in Water Resources. (2021). In S. Mohammad-Azari, O. Bozorg-Haddad, & A. Biswas, *Water pricing* (pp. 47-61).

Griffin, C. (2006). Water Resources Economics. *MIT Press*.

Helbling, T. (2017). *Externalities: Prices Do Not Capture All Costs.* International Monetary Fund.

The Economics of Food and Agricultural Markets. (2019). In A. Barkley.