AN INVESTIGATION OF URBAN WATER ECONOMICS AND THE ROLE OF PRICING IN DEMAND MANAGEMENT AND COST RECOVERY: DHAKA CITY, BANGLADESH

by

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Abstract

This study explores urban water economics and the role of water pricing in demand management and cost recovery for Dhaka City, Bangladesh. Dhaka Water Supply and Sewerage Authority (DWASA) is the responsible authority for supplying water to Dhaka city dwellers. Performance evaluation of the existing water supply system is conducted from operational and financial perspectives. Analysis of operational indicators demonstrates that DWASA is suffering from poor operational management policy, planning, and actions. Analysis of financial performance indicators establishes that DWASA is financially in deficit and requires efficient management policies and pricing structure to improve financial condition. Therefore, it requires overall improvement for ensuring long term sustaining future water supply for city dwellers.

Field surveys on consumer satisfaction and willingness-to-pay have been conducted for residential, commercial and industrial consumers in Dhaka City. Consumer responses were unsatisfactory for the satisfaction parameters set especially for quantity and quality. Short term and long term price elasticity of demand of tapped-water for residential and commercial consumers are -0.53 and -0.114 respectively. Price responsiveness of demand for commercial consumers is less then residential consumers measured for short term. However, willingness to pay is 6.6 and 17 times higher for residential and commercial consumers correspondingly. Different pricing options are formulated on the basis of long term for enhancing financial efficiency of DWASA in terms of cost recovery. Efficiency of pricing is investigated from economic point of view considering interests on consumers, producers and the society. From the outcomes of price-changing scenarios, it has been found that increasing tariff for residential consumers can be effective for increasing annual revenue for the water supplier. Increase in commercial water tariff produces negligible changes for supplier and in consequence no effect on annual revenue. This also confirms the findings that commercial consumers are inclined to use other sources of water supply rather than DWASA in case of increase in tariff.

This study concludes that water pricing has significant potential in managing water demand and recovering financial cost of water supplier in Dhaka City depending on consumer type, quality of service and duration of implementation. Public-private partnership is considered with potential as the solution to difficulties of consumers and DWASA at the same time.

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List of Abbreviations

ADB	Asian Development Bank
AC	Average cost
ADP	Annual development plan
AR	Average revenue
ANOVA	Analysis of variance
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
BUET	Bangladesh University of Engineering and Technology
CIA	Center of Intelligence
CP	Collection period
DCC	Dhaka City Corporation
DSM	Demand supply model
DTW	Deep tube well
DWASA	Dhaka Water Supply and Sewerage Authority
GDP	Gross domestic product
GNP	Gross national product
IBRD	International Bank for Reconstruction and Development
IWM	Institute of Water Modeling
MB	Marginal benefit
MC	Marginal cost
MCC	Marginal capacity cost
M cm	Million cubic meters
MIR	Management information report
MLD	Million Liter per Day
MNB	Marginal net benefit
MOD zones	Maintenance, operation and distribution zones
MR	Marginal revenue
MSE	Mean square error
MSR	Mean square regression
MST	Mean square total
MTk.	Million Taka (Currency of Bangladesh, 1 USD=69.74 Tk.)
MUC	Marginal user cost
MWR	Ministry of Water Resources
NRW	Non revenue water
O & M cost	Operational & maintenance cost
OLS	Ordinary least square
OR	Operating ratio
PED	Price elasticity of demand
PSP	Private sector participation
PPP	Public private partnership
SPI	Staff productivity index
SWTP	Surface water treatment plant
WAI	Weighted average index
WARPO	Water Resources Planning Organization
WASA	Water supply and sewerage authority
WR	Working ratio
WTP	Willingness to pay
UFW	Unaccounted for water

CHAPTER I

INTRODUCTION

This chapter introduces this research study comprising of four sections; 1) background of the research: general and study area; 2) statement of problem focusing on water demand, supply and allocation state in Dhaka City, Bangladesh; 3) objectives: main and sub objectives of the study; 4) scopes and limitations of the study revealing the capacity and possibility of the research.

1.1. General Background

Generally three possible scenarios for supply and demand of any given commodity exists, e.g., demand greater than, lesser or, equal to the quantity supplied. In case of demand exceeding supply, two methods are generally adopted, which are either supply augmentation or demand management and control.

Throughout the history of human settlement and development world-wide, water resources planning and management generally followed the approach of supply enhancement. Globally water demand has tripled over the last half-century. To meet increasing demand, the generally adopted strategy is to enhance water supply with several infrastructural measures e.g., building dams, extracting ground water by drilling wells, building water desalination plants, constructing reservoirs and so on.

Out of the above-mentioned structural measures, constructing large number of big size reservoirs or dams raise important environmental and social issues. The first limitation is of physical nature, as fresh water on Earth is of finite volume. Although fresh water is a renewable resource, the world's supply of clean, fresh water is steadily decreasing as quality of water is plunging downwards due to improper man-made interventions. Besides, the traditional methods of enhancing water supply ultimately can not produce more water than that is already available on earth; it can only divert water from one use to another by depriving some existing or future use of water. So, it can be inferred that water supply is usually in the stagnant mode. The second constraint behind decreasing esteem of supply enhancement is the high social, environmental and economic cost. Construction, operation and maintenance of the structures like large dam, reservoir call for initial and periodical huge investment. Moreover, the multi-disciplinary considerations give scope to divert water according to preference of uses, which may affect lifecycle of aquatic life forms and may also cause imbalance in the ecological and geomorphologic system. In addition, the large dams displace ethnic people causing social tensions. Its classic example is the Sardar Sarobar dam and other dams in the Narmada River and its tributaries in the Gujrat, Maharashtra and the Madhya Pradesh states of India. Besides, the reservoirs with time may get silted up making the purpose of the dam and reservoir frustrated.

All these constraints and limitations lead to the second approach termed as water demand management. As stated earlier, water has uses for various sectors like agriculture, industry, domestic, environmental uses, navigation, recreation etc. For the case of demand exceeding supply, it becomes important to devise strategies for water demand management focusing on economic efficiency, equity, environmental integrity, and ecosystem balance. These approaches are required to satisfy demands of consumers, suppliers and society as a complete entity. The methods or strategies of demand management are applied based on various economic instruments; tariff, tax, subsidy, quota, grants, tradable permit. These are promoted to attain a number of different objectives. Of the three Dublin Principles, the “instrument principle” requires water to be treated as an economic resource. Reasoning behind designating water as an economic resource are to (1) promote conservation and encourage privatization in the development, treatment and distribution of water resources; and (2) allow the improvement of water allocation and the setting of a charging scheme for water (GWP, 2000). Therefore, following law of economics, water pricing is considered as a possible means to manage water demand and promote thrifty water use.

1.2 Background of Study Area

Bangladesh is located in southern Asia in the northeast of the Indian subcontinent covering area of 1, 44,000 km². Most of the country is situated on deltas of large rivers flowing from the Himalayas. The population of Bangladesh was estimated at 150 millions of inhabitants (81 percent rural) with an annual growth rate of 2.056 percent in 2007 (CIA, 2007). The agriculture sector continues to play an important role in the economy of the country as major share of labor force by occupation are in the agriculture sector. 63% of populations are occupied in the farming, fishery, forestry sector, 11% are in industry and the rest are in services (CIA, 2007, FY95/96). GDP composition by sector is accounted by about 19.9% by agriculture, whereas industry contributes 27.61% and the rest of 52.5% by the services sector (BBS, 2006).

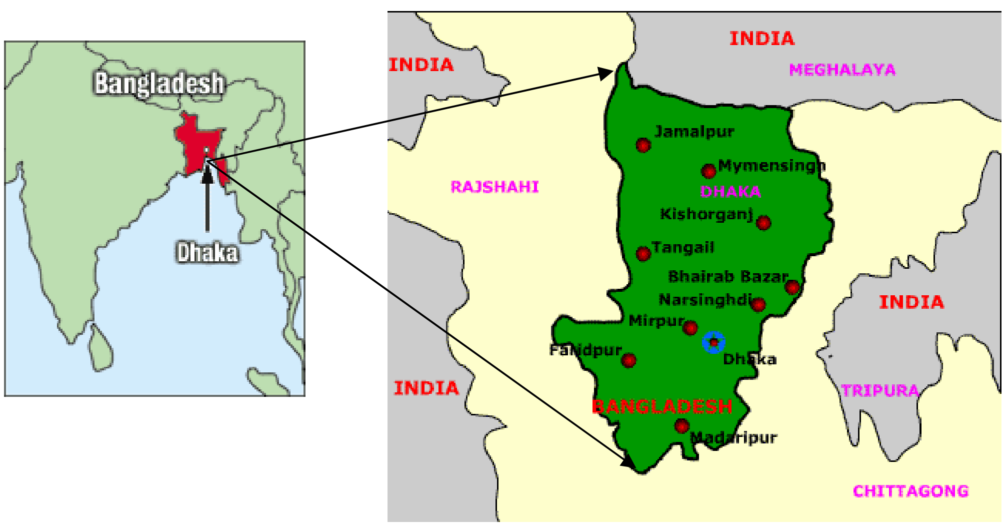

Figure 1.1: Geographical location of Bangladesh and Dhaka

Administratively, the country is divided into 6 divisions, of which there are four metropolitan areas. Among the six divisions, Dhaka Division is situated in the central region with an area of 31119.97 sq km and bounded by Meghalaya state of India on the north, Barisal and Chittagong divisions on the south, Sylhet and Chittagong Divisions on the east, Rajshahi and Khulna divisions on the west. Under the administrative authority of Dhaka Division, Dhaka City is situated at 23 43’ N Latitude and 90 24’ E Longitude. Climate of Dhaka city can be described as Tropical with heavy rain and bright sunshine in the monsoon and warm for the greater part of the year with annual precipitation about 2540 mm. Area of Dhaka metropolitan city is 360 sq km and population about 9.3 million (DCC, 2006).

1.3 Statement of Problem

River system flowing through Bangladesh is the third largest source of fresh-water discharge to the world's oceans. The annual volume of flows passing below the confluence of the Ganges and the Brahmaputra is about 795,000 cubic meters, which is equivalent to about 5.5 meters of depth over the country. In addition to that the country receives on an average about 2 meter rainfall annually. Still Bangladesh faces shortages of water every year for crop production and household consumption during several months of the year. At present, DWASA is able to supply 70% of water demanded by Dhaka City dwellers (Ali, 2006). Greater Dhaka's population is about 12 million and is growing at an estimated annual rate of over 5%. The city is characterized by unplanned expansion, with large squatter settlements in different parts of the metropolitan area. This has burdened an already inadequate infrastructure and caused environmental problems associated with insufficient water supply, sanitation, drainage, and urban flood protection. Deficiencies in water supply and sanitation services have resulted in higher costs for businesses, slower urban economic growth, and social unrest.

Water sector of Dhaka is suffering of several constraints; like haphazard growth, congestion, pollution and unplanned expansion including large squatter settlement in different parts of the metropolitan area. The core constraints are (i) groundwater aquifers are being depleted through overexploitation, and surface water sources of an acceptable quality are becoming distant from Dhaka; (ii) lack of funds for development; (iii) tariffs inadequate to cover both capital and O&M costs and (iv) poor management of the water supply and sanitation due to weak institutional capacity (ABD, 2006). Due to lack of specific research and planning regarding demand forecasting and demand management, water shortage is a never ending issue for the city dwellers.

Large-scale abstraction of groundwater and severe groundwater mining has led to a continuous falling of groundwater levels. Water supply or availability in terms of its origin; surface water as well as ground water also needs to be considered for the water shortage periods. Dhaka's groundwater table has dropped by up to 24 meters in nine years since 1996, bringing about a crisis in water output (BADC, 1997). This is causing several deep tube wells (DTWs) to dry up and thus lessen water supply. Dhaka Water Supply and Sewerage Authority (DWASA) has been drilling more and more deep tube wells, which now numbers 465, from 140 in 1990 to deal with water supply shortage as emergency water supply measure. However, this action has resulted in drying up existing wells at a rate faster than previous times and even the functioning tube wells are not being able to operate at their full potential. The situation is further exacerbated by large amount of non-revenue water (NRW), which includes technical and administrative losses (Rahman, 2007). Thus, water demand in Dhaka urban area has been estimated about 1999 MLD and the shortfall in comparison with water supply (1500 MLD) is 499 MLD in 2005. This shortfall is assumed to be 2929 MLD for water demanded 4419 MLD by the year 2025 (Mamoon, 2005). This situation calls for planning and application of water demand management strategies focusing on demands of consumers and producers to recover water supply cost, enhance level of efficiency and manage water demand.

1.4 Objectives of Study

The principal objectives of this study are to investigate water supply, demand and reconciliation scenario for short and long term condition. The specific objectives are as follows:

- To investigate water supply features of Dhaka City
- To investigate water demand features of Dhaka City
- To investigate potentially of pricing as demand management and cost recovery tool for Dhaka City water supply system.

1.5 Scope of Study

- Study is carried out in Dhaka Metropolitan area for existing water uses.
- For investigating water supply features the study is carried out for entire Dhaka City. Investigation of demand features of Dhaka City is focusing on zone II and zone III under the authority of Dhaka Water Supply and Sewerage Authority for maintenance, operation and distribution of water supply. Selection of zones has been based on nature of water use and population characteristics.
- Assessment is carried out based on primary and secondary data collected from public water sector organizations responsible for water supply, regulation and distribution. Face to face interview, questionnaire survey are used for primary data collection.
- Service efficiency and financial viability of DWASA are evaluated from responses of the water consumers as well as the reports published by DWASA.
- Various scenarios with current and alternative water tariff affecting consumers as well as producers are analyzed. Social welfare is reflected as core accent of water policy decisions.

1.6 Limitations of Study

- Due to time constraint, consumer survey for water demand, willingness to pay and satisfaction has been conducted for only two MOD zone areas out of seven under authority of DWASA.
- Water demand model has been developed only for residential consumers.
- Water consumption in terms of quantity for water demand model has been derived from water bill and water tariff.
- Economic analysis is focused on residential and commercial water use only.
- Role of water pricing in cost recovery has been explored from increase in revenue approach.
- Survey was conducted in winter season when water shortage is not of severe concern and thus there are fewer complaints of water supply and people in Dhaka City are highly price responsive regarding their water use.

CHAPTER II

LITERATURE REVIEW

2.1 Background

Dhaka City has been growing at a fast pace over the years. The city area expanded 46% within the time span of 1990 to 2000 (JICA Baseline Study, 2000) and in the process of expanding much more. In 1963, Dhaka Water Supply and Sewerage Authority (DWASA) started its mission to supply water for domestic, commercial, industrial consumers and to dispose of sewerage with storm water drainage. Dhaka City has been growing with additional pressure on its existing water supply network and system and now supplying about 516.92 Millions of cubic meter water per year (DWASA, 2007).

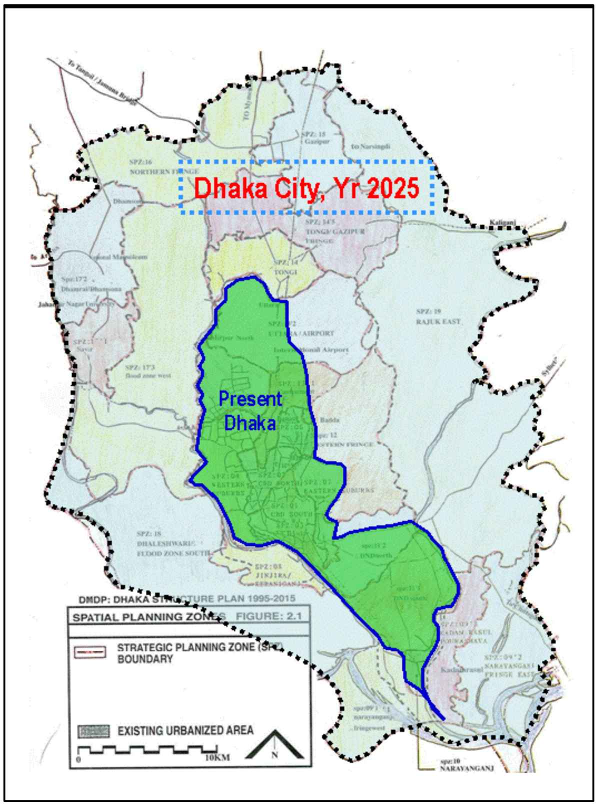

Figure 2.1 Expansion of Dhaka City (Source: Azam, 2006).

History of DWASA demonstrates immense expansion in terms of water supply over last 50 years or so. In 1963, DWASA supplied 130 thousands of cubic meters per day and which has increased 13 times over 40 years of time (Mamoon, 2006). Then again, water demand of the city dwellers is not often met by DWASA supply which means that demand exceeds supply and widening the gap quite immensely with time. There is a prevailing economic wisdom that says demand exceeds supply only when the established price for the consumers is not right or balancing. DWASA's history of water supply over last 50 years states the fact that it has focused mainly on supply enhancement programs by increasing number of DTWs from 30 in 1963 to 465 in 2007.

There are numbers of consequences to consider regarding this approach. Among them, continued depletion of ground water level is an alarming one. The following figure demonstrates ground water level depletion underlying Dhaka City over last ten years. In last 10 years, water level has dropped more 60 meters and will continue to do so if supply enhancement is continued by installing more and more DTWs. Declining groundwater level increases the risk during earthquakes as it could lead to subsidence of the clay soil plate Dhaka is situated on (The Daily Star, 2008).

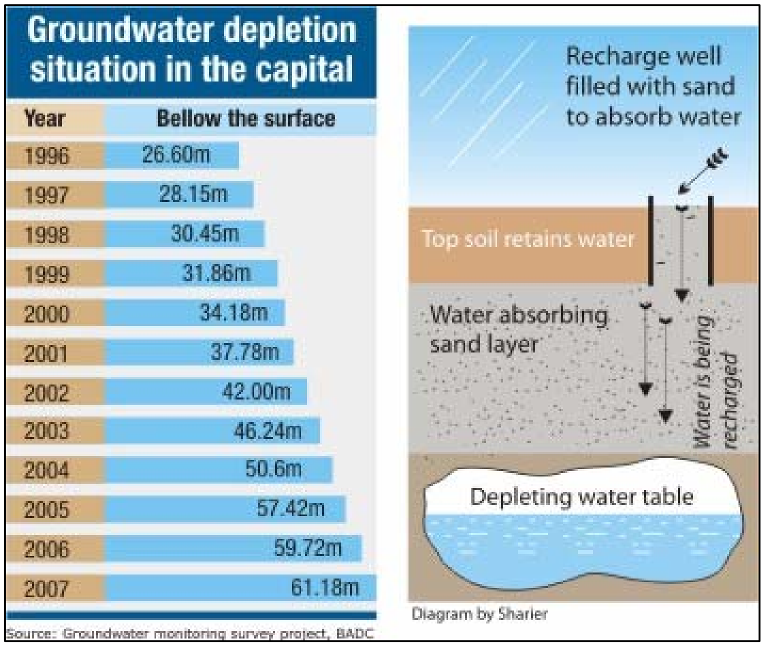

Figure 2.2 Groundwater depletion and diagram of aquifer underlying Dhaka City.
Source: The Daily Star, 2008

Population of Dhaka city has grown from about 1 million in 1971 to more than 12 million in 2005. It has also been estimated that by 2030, this city will be the 2nd largest city in the world housing over 25 million people (Yusuf et al, 2007). Economic advancement and development aids in augmentation of water demand. It is said that water is a heavy commodity relative to its value (Griffin, 2006). Thus pumping, conveyances are in heavy chance of becoming quite expensive which is a big matter of concern as Dhaka City is currently dependent on pumping of ground water and thus on electricity and diesel. The other option is river water surrounding periphery of Dhaka City which is highly contaminated with deteriorating quality (ADB, 2006).

It has been acknowledged by the Government of Bangladesh that changes in water pricing are required to promote economic efficiency of water demand and supply in Bangladesh. It is considered that a system of cost recovery, pricing, and economic incentives/disincentives is necessary to balance the supply and demand of water. The National Water Policy (1999) recognizes the fact in long run public water supply utilities will be autonomous entities with effective authority to charge and collect fees focusing on cost recovery to promote water conservation and stop water wastage and pollution.

The possible scenarios with present circumstances explained above leads to the other method to apply in the case of demand exceeding supply is demand management strategies. There are several established strategies; rationing water use, educating water users to conserve water, establishing water conservation plumbing codes, raising water rates (Griffin, 2006). These strategies are mostly employed to obtain economic efficiency while managing demand with equity and fairness to all stakeholders.

This chapter explores the possible options of water demand assessment and demand management strategies employed universally. The preceding works on various strategies and their methods are discussed and fundamental economic theories related with economic pricing are explained as well. Concepts of economic analysis have immense potential to design economically efficient demand management strategies and plans.

2.2 Conceptual Framework

2.2.1 Cost, Revenue, Demand, Supply and Willingness to Pay

In the case of urban water supply various costs are needed to be in consideration. Fixed cost along with variable or operation and maintenance cost are considered for computing both average and marginal cost. Average cost of supplied water is total cost divided by amount of water supplied which is lower per unit for more production. Whereas, marginal cost is the cost for producing an additional unit of good .This is the derivative of total cost with respect to quantity. Marginal cost or supply curve describes the relationship between the quantity of a producer's good or services and their marginal production cost. In case, of natural monopoly, the marginal cost is always lower than average cost. Average cost starts to decline as per unit cost of production is lowest as single producer supply water to maximum number of consumers (Griffin, 2006).

Demand curve or marginal benefit or willingness to pay curve describes the marginal benefit and quantity relationship for a particular commodity for any consumer. This curve represents what the consumers are willing to pay for various quantities. The amount an individual is willing to pay to acquire some good or service (UNEP. 1995). WTP is the maximum monetary amount that an individual would pay to obtain a good. This technique can act as an indicator of the value of any good to a community (Field, 1997). Contingent valuation method is often used for direct measurement of WTP by enquiring people about their choices of payment on requiring certain quality of service. Contingent valuation is a survey-based economic practice for the valuation of non-market resources; environmental resources like water supply, availability.

Revenue sufficiency of water supplying utility promotes concept of average cost pricing. In this case, total revenue needs to be equal to total cost (Griffin, 2006). Even then, there are considerable loss in efficiency as average cost are less than marginal cost as quantity demanded will be higher for average cost pricing than marginal cost pricing. Efficient pricing is thus considered as marginal cost pricing.

2.2.2 Surplus Efficiency

The consumer surplus is the amount that consumers benefit by being able to purchase a product for a price that is less than they would be willing to pay for. In case of water, consumer surplus is the motivation for consumers to buy water and represented in terms of net Willingness to pay and is the area below demand curve, limited by price.

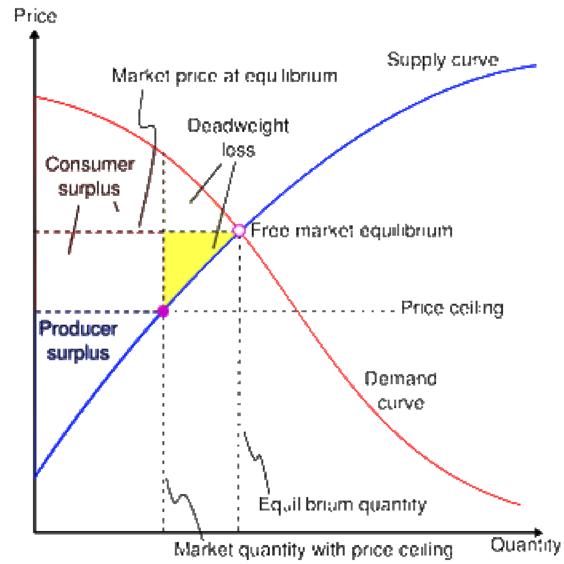

Figure 2.3 Social Welfare and dead weight loss (Case & Fair, 1999).

Producer surplus is the difference between the amount that producers actually receive and the minimum amount that they would have to receive in order to supply the given level of output. At the same time, producer surplus is the net benefit of the producers and is represented by area above supply curve limited by price (Salvatore, 2001).

Deadweight loss is the inefficiency which is mostly presumed or pricing changing policies. By imposing tax or subsidy a difference between the consumer surplus and producer surplus can be observed. The difference is termed as dead weight loss which is not affecting any ones welfare.

Sum of consumer surplus and producer surplus provides approximation of the net benefit of goods or services. In the case of equilibrium, sum of consumer and producer surplus is at the optimum (Agudelo, 2001). Equilibrium condition is plausible to achieve when there is perfect market condition or supply equaling demand.

2.2.3 Price Elasticity of Demand

Price elasticity of demand (PED) is the indicator to reflect relation between changing price and demand. General conception states that an increase of price leads to decrease in demand and the vice versa. The demand for a good is considered inelastic if the change in quantity demanded does not vary with change in price. Inelastic demand is commonly associated with "necessities". The goods and products with substitutes available are usually elastic. Greater than 1 value for elasticity states the elastic nature of a good and vice versa. The formula for calculating the coefficient of price elasticity of demand is:

$e = \frac{\Delta q / q}{\Delta p / p}$; p=price, Δp=change in price, q=quantity, Δq= change in quantity;

(Salvatore, 2001)

2.2.4 Economic Policy Analysis

Following empirical approach, any policy can be used to estimate monetary value of prospective new benefits and compare it to the same of prospective new costs.

Maximization of net benefit is considered as efficiency criterion for a good policy change. Bringing all policy effects into a single net benefit measure can bring out both useful and harmful results. In water related situations, net benefit calculations are heavily influenced by water demand functions. Residential or domestic water uses are most of time prioritized even when maximum net benefit can be obtained from industrial water use (Griffin, 2006). Baseline consumer welfare can be explained by the following figure.

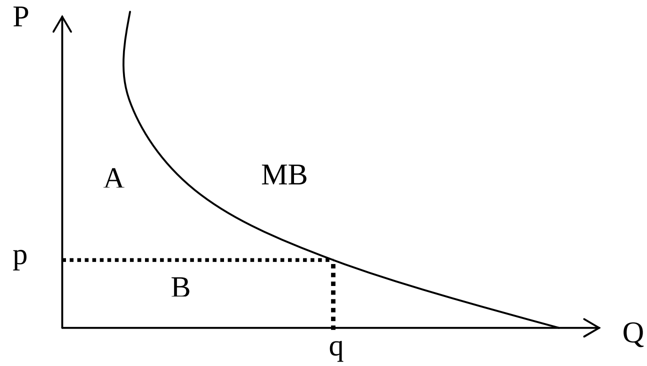

Figure 2.4 Baseline consumer welfare.

This figure explains initial, pre-policy circumstances for any group of water consumers. This curve can be used for households, industries, or any combination of water using agents. MB can be of any group's collective demand for retail water supplied by a utility. This utility meters water deliveries and charges p per unit of water. In response, the consumer group chooses to take w units of water. Total benefits received by water users are then the area under their demand, area (A+B). Total revenue received by the utility is p time's q or area B. Net benefits received by water users is area A.

Policy changes affecting people or business will alter the net benefits received by these agents through at least one four primary mechanisms: price rationing, quantity rationing, demand shifting, or supply shifting. Potential increase of price from p_2 to p_1 can lessen water quantity demanded from q_2 to q_1. At price, p_2, net benefit of consumers is (a+b+c) which becomes only a after price becomes p_1. At the same time, utility revenue changes from (d+e) to (b+d). This can also affect utility's production cost by lowering the amount of water to process. Utility's cost function needs to be reevaluated after this price change.

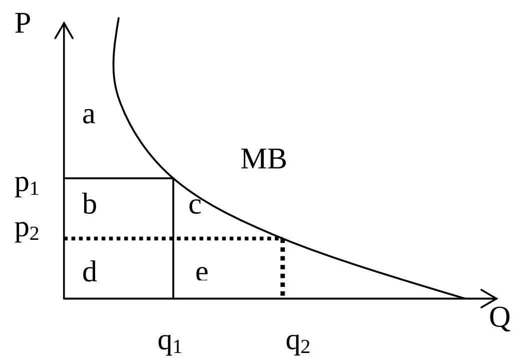

Figure 2.5 Effect of price and quota rationing policy.

Reducing water use by limiting quantity from q_2 to q_1 with constant water price of p_1 can produce several changes. Consumers lose net benefit of area c and utility will loose revenue of area e. Although, consumers are loosing net benefit of area c here, but, they are loosing area (b+c) for price rationing policy (Griffin, 2006).

2.3 Water Demand Assessment and Analysis

Designing appropriate water demand management strategy requires comprehensive knowledge of urban water demand determinants. Water demand is not just any value but a function (Griffin, 2006) which can be assessed using cross-sectional (observations at a single point in time), time-series (observations over time), panel data (both time-series and cross-sectional observations) and multidimensional panel data (observations across time, cross-sectional, and across some third dimension) (Salvatore, 2006).

Several methods are available for estimating water demand with different data requirements, limitations and specialties for different sectors. In the case of estimating urban water demand, three methods have been identified; point expansion method, statistical regression and contingent valuation methods (Griffin, 2006). The point expansion method requires elasticity value which needs to be generated by another method or used from secondary literature review. Statistical regression is commonly used for estimating water demand in residential, commercial and industrial sectors using demand as a function of several variables. Contingent valuation method uses hypothetical nature of survey questions to judge non-market valuation.

There have been numerous studies on water demand estimation dated from mid fifties to present. According to Rosegrant et al (1997), domestic water demand is a function of population growth, per capita income growth and income elasticity of domestic water demand. Residential water demand varies greatly according to the location, the climate, and socio-economic variables. Residential or domestic water demand is often found to be a positive function of the number of individuals in the family, the size of the house, the number of water-using appliances, and household income (Lyman, 1992; Renwick and Archibald, 1998; Renzetti, 2002). In addition, weather has an impact (mostly on outdoor water use), increasing with temperature and decreasing with rainfall. Whereas, industrial use of water is based on water use intensity per unit of gross domestic product (GDP) and its growth rate (Rosegrant et al, 1997).

Several models have been formed for assessing water demand and supply. A major portion of these models construct demand supply models for agriculture water use and management. Among these, McCarl et al (1999) provides a ground water study based on maximizing regional net benefits across multiple sectors like agriculture, industry and municipal. The primary application of this model is to compute and contrast costs for different policy approaches to spring flow protection. Brooker and Young (1994) have developed one surface water single basin model for agriculture, hydropower, thermal energy and urban water demand and supply. Here, urban water demand is constituted of commercial, industrial and residential water demand. Basin wide net benefits are maximized for four scarcity-sensitive demand sectors located at different places along the river. The above two mentioned models do not have any dynamic or stochastic elements and focused on maximizing NB. There is one other model developed by Newlin et al (2002). This model allocates water among several sectors like agriculture, commercial, hydropower, industry, residential using minimize cost objective function for surface and ground water (Griffin, 2006). All of these models were developed for DSM in North America region.

In recent years, urban water demand estimation reports are becoming available for developing countries as well. Water demand is considered to be function of socio-economic, climate and pricing variables. So, it is required to adapt demand estimation equation for different countries with recent years of data. Economic analysis of urban water use in Sri Lanka has been conducted by Hussain et al (2002). Monthly aggregate country level data have been used for different sectoral water use. In this case, price of water, consumer income, and population and its growth rate, level and type of economic activities and weather conditions are considered as influential variables for specifying water demand model. Price elasticity of demand and income elasticity of demand found for the residential water users in -0.18 and 0.47. Price elasticity of demand found for the commercial and industrial water uses are respectively found as -0.17 and -1.34. It shows huge responsive to price for industrial water consumers.

In 2006, Institute of Water Modeling (IWM) has conducted water demand survey under the Resource Assessment and Monitoring of Water supply sources for Dhaka City Project. Results were utilized for formulating water consumption per person per day model using regression model. Housing type and use of living standard gadgets or amenities like car washing facility or dishwasher were considered for this model. Different water users were interviewed out of which 93% respondents confirmed DWASA as their major source of water. Industrial along with commercial water demand is estimated at 10% of the total water demand. The final report on Demand management, water abstraction strategy and monitoring system published by IWM contains water demand forecasted for DWASA. Total water demand is calculated using water demand per capita per day living in individual type of house. The simulation model used data from 2005 as base data. 15 variables were used for simulation of this model over a 25 years time period (2005-2030). Baseline water demand for year 2005 is considered as 1606 MLD which is expected to rise about 2.5 times to 4073 MLD in another 25 years. Five different scenarios are considered for simulating alternative management situations. Microsoft Excel was used for assessing the cases; leakage improvement, growing vertical rise, restraining use of water-gazzling gadgets, combination of first two and combination of the first three situations. Development for pricing policy for water demand management has been recommended considering standard of living and required consumption quantity.

Variables for defining water demand forecasting model varies from time to time and place to place. Geographic location, climatic condition and water uses are diverse in nature. Reliable data availability on daily, monthly or annual basis is another important factor for developing dependable model.

2.4 Pricing as Water Demand Management Tool

A common market–instilled notion is that in the case of demand exceeding supply for any commodity, price is too low. Price is the considered to be the policy tool which can balance quantity supplied and quantity demanded. So, when it is required to manage water demand, then water pricing is an important policy tool to explore.

Anything scarce and in demand commands a price. It is important for water price to reflect economic, social, and environmental costs including the opportunity cost and externalities of water (GWP, 2000). In reality, water pricing is a volumetric price placed on metered water. Often, tariff or rates are charged to the consumers in exchange of water supply by water suppliers (Griffin, 2006). In theory, water for each specific use has a “right” price, at which all costs can be recovered, including environmental and social costs. This price will provide the right level of incentive for water use reduction and efficiency. There can be two major objectives behind pricing. These objectives are economic efficiency by which water users can get maximized Marginal Net Benefit (MNB) and revenue sufficiency for the suppliers. It also promotes concepts of equity and fairness by charging same price for all the users or users of one sector (Asad et al., 1999)

In practice, this right price is considered non-existent because estimating the marginal cost of water supply, which determines the price is difficult and likely to be resource-consuming, as there are no standard methods or system for doing that. Further, the environmental externalities of water use are poorly understood and vary with time and space (Environment Canada, 2004). In the short run, since water utilities are a capital-intensive industry, the average cost, which includes the fixed costs, is usually higher than the marginal cost. Therefore, with time passing, average and marginal cost both lessen. However, in the longer run, if new capacity is required, the marginal cost (which shows the cost of the new infrastructure) can become higher than the average cost including both the new infrastructure and the water produced by the old infrastructure. Revenue sufficiency promotes the idea of average cost pricing whereas economic efficiency requires marginal cost pricing (Griffin, 2006)

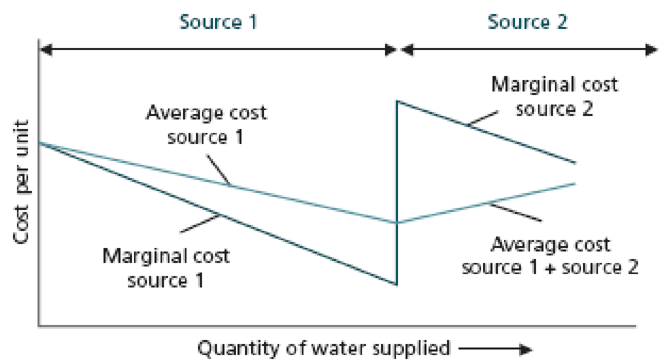

Figure 2.6 Change is average and marginal cost with change in supply.
(Environment Canada, 2004)

In case of depletable water supply, marginal user cost (MUC) which is the future value of Depletable water discounted to today (Griffin, 2006) is included. Limited capacity of system is also considered by adding another component to pricing as marginal capacity cost (MCC). MCC may vary from year to year (increasing or decreasing) but MUC always rises with time. Thus, economic pricing for depletable water sources is

$$Price = \frac{\delta C}{\delta Q} + MCC + MUC\,;\ \frac{\delta C}{\delta Q} \text{ is the volumetric cost component of water}$$

(Griffin, 2006)

A case study was carried out for multi-sectoral water allocation in Lebanon. The study focused on to achieve highest economic return from water use by evaluating current water prices, allocations against price of water and optimal allocation among different sectors. Linear mathematical model was developed for maximized net annual revenue from agriculture and residential water uses. Several constraints for five different scenarios were examining for optimal multi-sectoral allocation pattern. A comparison between the current water charges and the cost of water supply had been done and the coverage of water charge for real water supply was also calculated (Qubáa et al, 2002).

Water allocation policy modeling for Mekong (Ringler, 2001) and Dong Nai river basins (Ringler et al, 2006) are based on water allocation among different sectors with the objective to determine tradeoffs and complementarities in water usage and strategies for the efficient allocation of water resources. The model developed is aggregated with country/regional-level water supply and demand, and economic benefit functions and solves for optimal water allocation at the basin level subject to a series of physical, system control, and policy constraints. The optimal allocation of water across water-using sectors is determined on the basis of the economic value of water in alternative uses.

Different countries have different background reasons for charging water. The reasons and structures of water tariff are changing with time. Availability of water is playing a big role in this case which in turn is supporting water conservation and water demand management. It is explained by Amin (2005) that pricing of urban infrastructure and service provisions requires focusing on WTP, ATP along with subsidization and cross-subsidization. In some cases, country economy plays supportive role to reform water tariff structure as the findings from Dinar and Subramanian (1997) explained that high income countries are more flexible to reform pricing policies and thus recover water cost. Then again, importance of water pricing reflecting the cost of water supply for generating funds to expand service and for promoting efficient use (Amin, 2005) is becoming well realized among policy makers in developing countries little by little.

Therefore, it can be said that water demand management is an important concept for controlling continuously increasing urban water demand. Water pricing is a significant mode of communication between the consumers and producer. Different variables affect water tariff structure which in turn causes changes in water consumption or demand.

2.5 Public-Private Partnership (PPP)

Public-private partnership (PPP) has become a preferred financing scheme over the years with large number of developing countries. Several reasons affecting this new phase of preference are identified by World Bank Institute (2008) and these are mainly to achieve value for money (VfM) while delivering better quality of services by public sector. The other reason is to increase infrastructure provisions and services within budgetary and fiscal constraints. For developing countries where public services lacks investment budget with declining interest from the foreign aid donors are now more interested in this scheme to achieve financial sufficiency with ability to provide quality service to consumers.

In the case of PPPs introduced into public services, responsibility for many elements of service delivery may transfer to the private sector, but the public sector remains responsible certain matters specially for,

- Decision making on the level of services required, and the public sector resources which are available to pay for them;
- Establishing standards for safety, quality and performance standards of services and,
- Enforcing standards and regulations imposed by the Government on private services.

(The Stationary Office, 2000)

The Stationary Office under United Kingdom Treasury Office further realized that recognition of the contributing factors by the public and private sectors can develop a comprehensive and successful partnership. The Government as the authority of public services has existing infrastructure with trained staff and collaboration with other government agencies. This networking and database of past works and relevant works can also be helpful in operation procedure of PPP. Private sector offers commercial incentive which ensures cost recovery and future investments. Innovative approaches to deliver quality service to consumers and management expertise are the other potentials offered by private sectors.

In 2006, Jensen and Blanc-Brude attempted to identify the reasons behind increasing Private Sector Participation in for water sector in developing countries. Negative binomial regression model is used to investigate the factors influencing the number of private sector participation (PSP) projects in a sample of 60 developing countries with 460 PSP projects. The regression results provide support for the hypotheses that PSP is greater in larger markets where the ability to pay is high but governments are fiscally constrained.

Jensen and Blanc-Brude (2006) found that demand for higher coverage levels and constraints on government finances are significant variables in estimating PSP contracts signed. The results of their analysis supports that private investors are more likely to engage in PSP where institutions support government commitment to uphold contracts or implementing established regulatory rules. The relevant institutions are: protection of property rights; enforcement of contracts; rule of law; ability of the bureaucracy to implement policies and rules; political stability; control of corruption. This further supports that developing country governments engage in PSP when demands for increasing coverage or quality are high. Willingness to pay and Affordability to Pay are required to be high private sectors to participate for PPPs.

CHAPTER III

METHODOLOGY

This chapter elaborates the research framework and the methods chosen for conducting research work. Study area, data collection method and formulation of model are discussed in detail in this section.

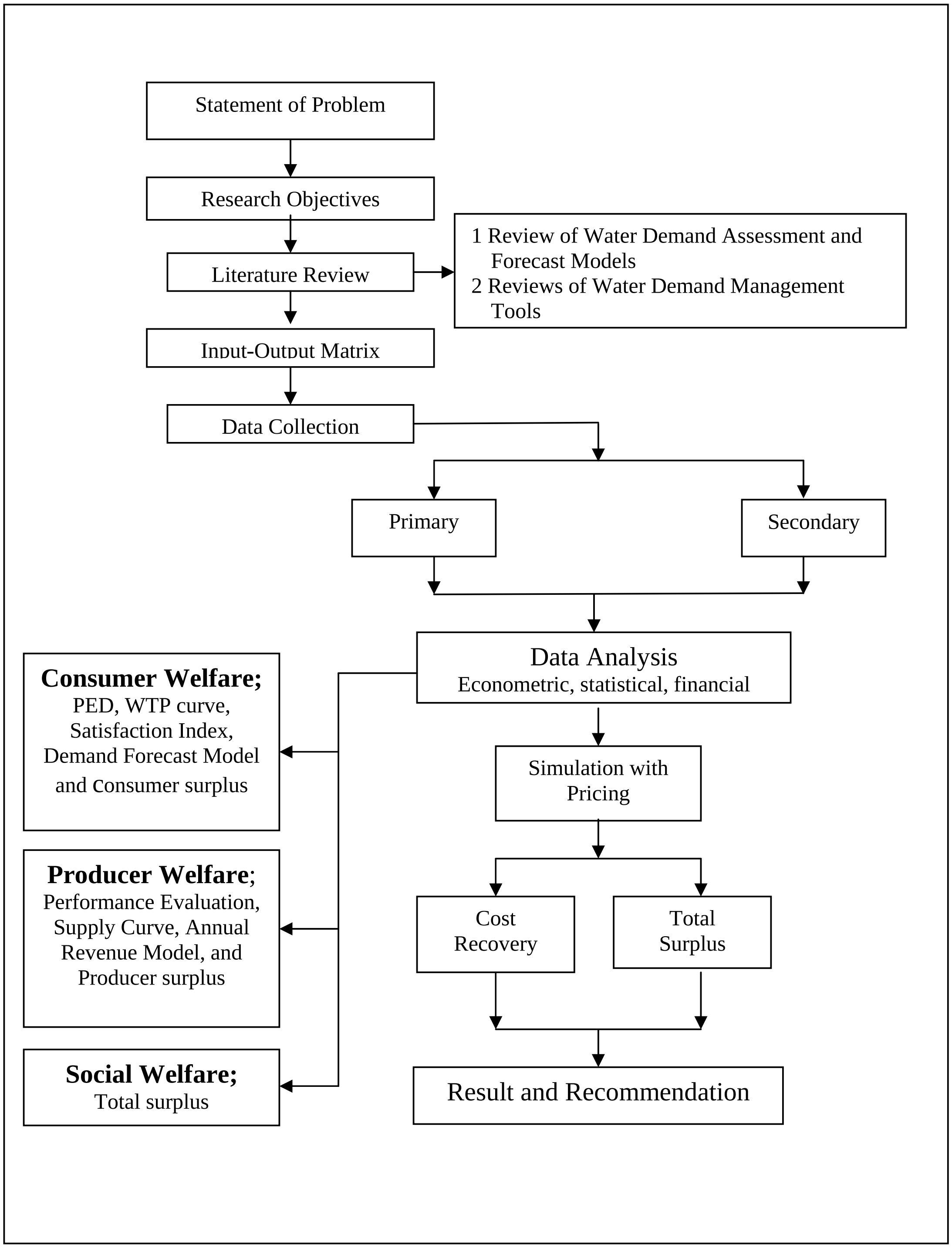

Figure 3.1 Research Design Framework

3.1 Framework for Study

Table 3.1 Input/ Output Matrix

Sub-Objectives	Activities	Input	Output	Source
To investigate water supply features in Dhaka City	Investigation of operational efficiency indicators	Production per capita, average consumption % of NRW, Storage capacity, total supply coverage, water supply source, type.	Operational efficiency.	Secondary; DWASA
	Investigation of financial efficiency indicators	Capital cost, working capital ratio, revenue collection, O & M cost, revenue per connection, full supply cost, water tariff for residential, commercial, industrial use, change of tariff over time, life duration, Maintenance rate over the life duration (T), discount rate	Cost recovery, role of subsidy for water charges	Secondary; DWASA
	Investigation of service indicators	Type of water supply, supply pressure, reliability of water supply, water quality satisfaction	Service quality of water supply	Secondary; DWASA, BUET, BBS Primary; HH survey
	Investigation of institutional indicators	Regulatory and accountability mechanisms, information, research, and technological capabilities, policy for pricing and cost recovery, accountability provision, functional capacity.	Institutional set-up of water supply	Secondary; DWASA, WARPO.

Table 3.1 Input-Output Matrix (Contd.)

Sub-Objectives	Activities	Input	Output	Source
To investigate water demand features of Dhaka City	Questionnaire survey; residential, commercial and industrial consumers	Users perception of water supply	Satisfaction of the consumers about quality of service	Primary; field survey
	Questionnaire survey; residential, commercial and industrial consumers	Users perception of water tariff	Willingness to pay of the consumers, Demand curve for different water uses	
	Contingent valuation survey; residential, commercial and industrial consumers	Consumers response for cost and benefit of water use	Price elasticity of demand, relation with utility revenue	Primary; field survey
	Data collection for marginal/ average cost and questionnaire survey for MB	Water tariff, users response about benefit	MNB for domestic, industry, commercial users	Primary; field survey Secondary; DWASA
	Identification of features affecting water supply and demand in Dhaka City	Water demand determinants	Household water demand model.	Primary; field survey Secondary; BBS, DWASA.
To investigate pricing for reconciliation demand / supply, demand management	Assessment of reconciliation system: matching demand / supply	Annual revenue determinants	Annual revenue model; influencing variables	Secondary; DWASA
	Testing for cost recovery scenarios	Simulated options	Revenue options	Primary; field survey Secondary; DWASA.
	Assessment of pricing as a tool for social welfare	Marginal benefit, marginal cost curves with maximum willingness to pay	Consumer, producer and total surplus	

3.2 Study Area

Dhaka City is located in the central region of Bangladesh at 23°42′0″N, 90°22′30″E, on the eastern banks of the Buriganga River. The city lies on the lower reaches of the Ganges Delta and covers a total area of 815.85 square kilometers (315 sq mi). Dhaka experiences a hot, wet and humid tropical climate. The city is within the monsoon climate zone, with an annual average temperature of 25°C (77°F) and monthly means varying between 18°C (64°F) in January and 29°C (84°F) in August. Dhaka is located in one of the world's leading rice and jute-growing regions. In Dhaka City, small scale industries; plastic, garments industry, foot ware, textile mills, printing and dying factory, biscuit and bread factory, pharmaceutical industry, cosmetic industry, soap factory, rice mill can be found within the city boundary area. The tannery industry is a large industry which is at present located at Hazaribag area which is situated in Dhaka City area. But then again, the Government is planning to relocate this industry outside of the main city area within the time span of next two years.

Dhaka city is administratively divided into thanas and then wards which are under the authority of Dhaka City Corporation. DCC operates diversified functional activities like urban planning, building control, public safety, water supply and drainage. Mainly, managing private sources of water supply, drainage schemes, and public water courses are under the jurisdiction of DCC regarding water supply and drainage. Whereas, Dhaka Water Supply and Sewerage Authority (DWASA) performs the responsibility of supplying potable water to domestic, industrial, commercial water users mainly in DCC area. DWASA coverage is briefly explained in figure 3.2.

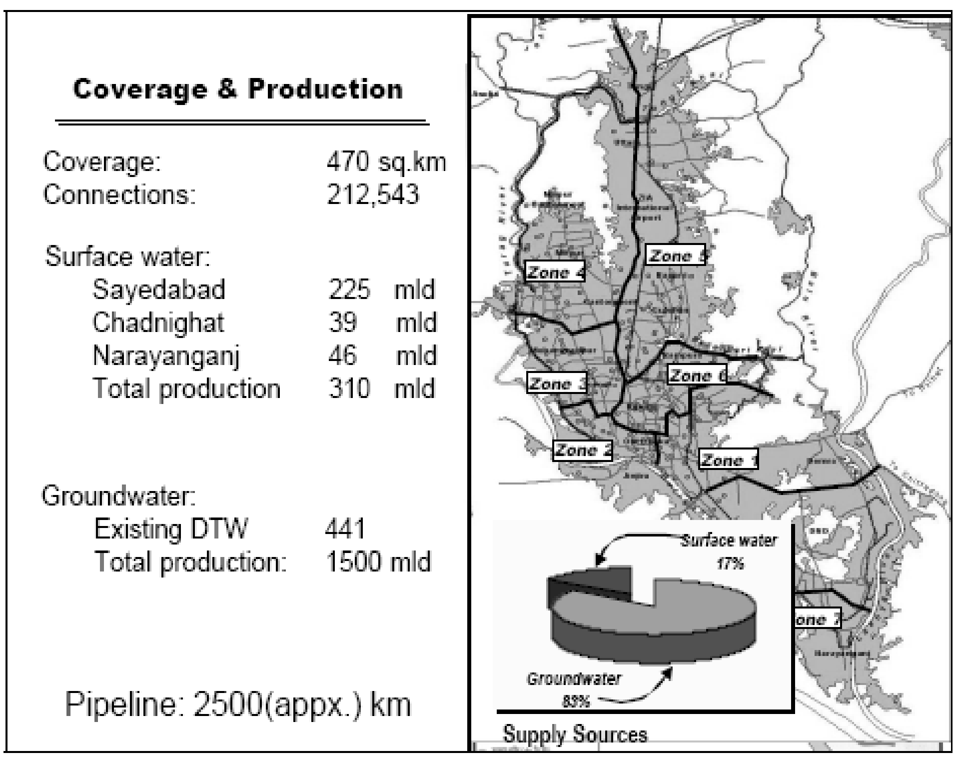

Figure 3.2 DWASA distribution coverage and production (Source: Mamoon, 2006)

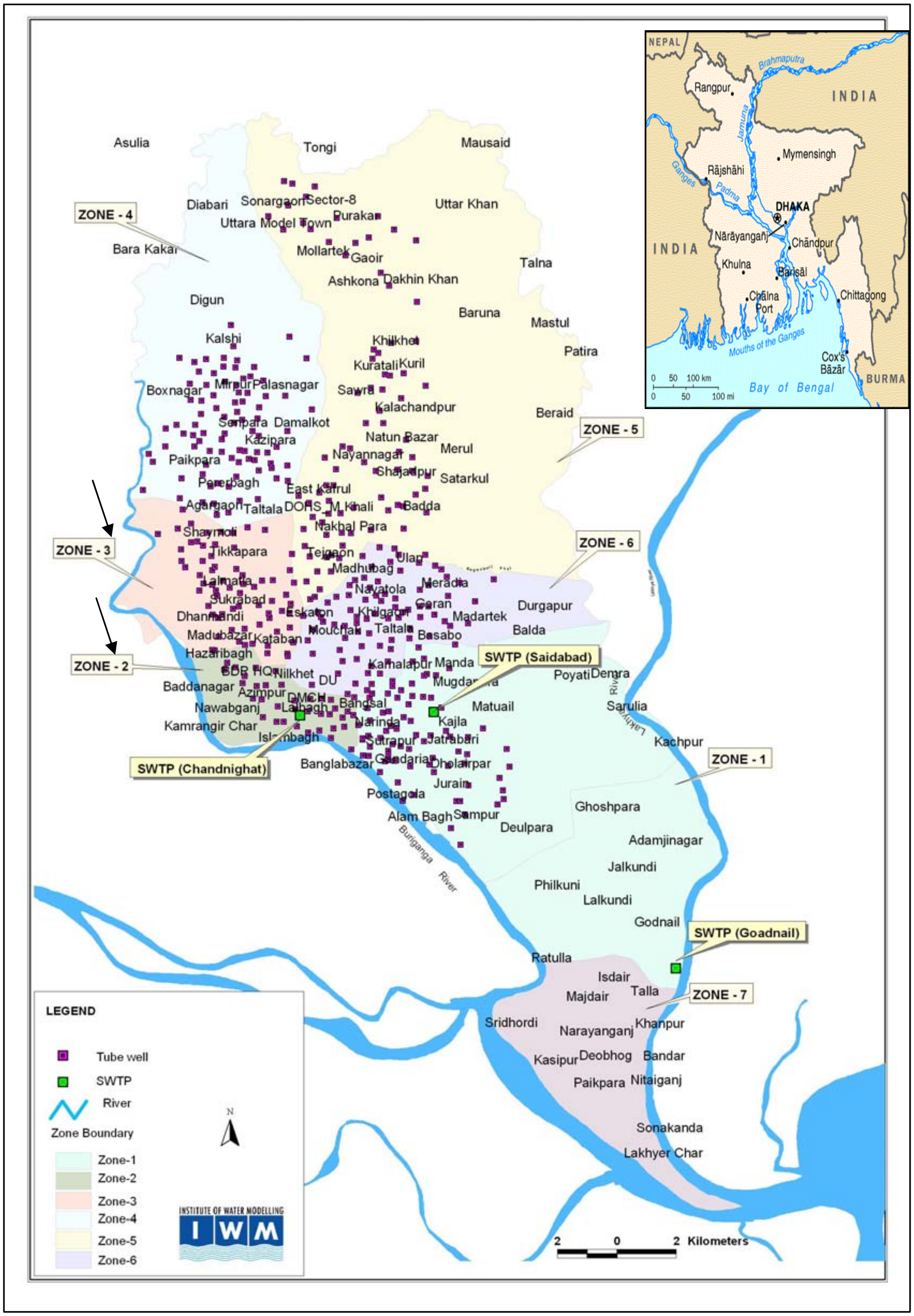

Figure 3.3 Periphery of DWASA (source: IWM, 2007)

Dhaka city is guarded by several peripheral rivers. It is bordered by Tongi khal and Turag River in the north, Balu River in the east and Buriganga River and Dhaleshwari River in the West and South. Better employment opportunities, educational facilities, health facilities and mainly urban amenities have drawn people to Dhaka City for a long period of time. The city has grown considerably over time. The following table can provide the picture of population growth and areas expansion of Dhaka City over last 50 years.

The study area is the major inhabited area of Dhaka city under the jurisdiction of DCC and coverage of DWASA. There are seven zones under DWASA authority of water supply and sewerage. For investigating water supply features of Dhaka city, data from all the seven zones has been collected via secondary sources.

Table 3.2 Areal expansion and population growth of Dhaka City.

Year	**Area (sq km)**	**Population in Million**	**Density person/sq km**
1951	85.45	0.4	4681
1961	124.45	0.72	5785
1974	335.79	2	5956
1981	509.62	3.44	6750
1991	1352.87	6.48	4790
2001	1528	10.71	7009

Source: Bangladesh Census 2001

Areal expansion in above table includes the extended Dhaka City areas, whereas the service area for DWASA is mainly inside the Metropolitan City area. Estimating annual growth rates of different thana areas in Dhaka City, the actual and projected population for DWASA service area is given as follows:

Table 3.3 DWASA service area population

Year	**Population in Million**	**Remarks**
2001	7.41	Actual
2005	9.165	Base year
2010	11.1	Projected
2015	13.32	Projected
2020	15.89	Projected
2025	18.75	Projected

Source: Dhaka Water Supply Project Mid term Report, May 2006

Among the seven zones, zone II and zone III are selected for conducting survey on consumer satisfaction and willingness to pay. Survey area selection criteria are dependent on several factors. According to Dhaka Water Supply Project report published by ADB, residential or domestic water demand is the major factor of total water demand in Dhaka City. Zone II is the most unique place in Dhaka City comprising of residential, commercial and industrial water uses. This is old part of Dhaka City with narrow lanes and high population density. All the lanes comprises of different commercial activities. At the same time, the buildings are mostly used for residential and commercial purposes. One part of the zone II is not included in DWASA coverage. Hence, for survey purpose, this area is also investigated.

Zone III is more of the modern segment of Dhaka City. Zone II and Zone III are adjoined to each other and the immediate difference can be observed. Water consumers of Zone II and Zone III are mostly residential. From observation, several aspects of water users have been identified. In Zone II, the water users use their own residence for multipurpose activities. There are large numbers of houses with shops or restaurants in front of them. They are not aware of the difference between water tariff between residential and commercial consumers. That is why, irrespective of water use categories, people are paying water tariff as domestic water users. This same incident has been observed at Zone III also. There are some numbers of industrial water users in Zone II, but the number is very minor for Zone III. Six thanas in total were surveyed for collecting primary data. Land use characteristics and location of these thanas are illustrated in the following table.

Table 3.4 Land use characteristics and population density of survey areas

Sl No	Name of Thana	Location	Present Land Use Characteristics	Population Density Per Sq. km
1	Hazaribagh	Zone II	Congested industrial and residential.	22.39
2	Kamrangir Char	Zone II	Congested residential area for low income people	39.011
3	Kotwali	Zone II	Old Dhaka City; Congested residential, commercial and small scale industrial	135.42
4	Lalbagh	Zone II	Old Dhaka City; Congested residential, commercial and small scale industrial	82.12
5	Dhanmondi	Zone III	Mostly residential with mixed use of commercial, educational and health.	42.305
6	Mohammadpur	Zone III	Congested residential and mixed use	37.58

Source: ADB, 2006 & Population density from Census, 2001

3.2.1 Ground Water Profile of Dhaka City

The aquifer system underlying Dhaka City is part of the Dupitila sand formation. This formation has three aquifers of which the upper two layers are mainly exploited for water supply purposes. The upper most aquifer is about 25 m below ground level with thickness of 70 m. The next one is about 120 m below ground level and thickness level of 35 m. The lower aquifer is about 185 m below ground level with a thickness of 95 m. DWASA and privately owned deep tube wells extract about 700 Mm^3 water per year causing 2-3 m of water table fall per year. DWASA extracts another 45 Mm^3/annum from the lower aquifer using 29 wells. The tentative safe yield is estimated at 600 and 139 Mm^3/annum for the upper and lower aquifers respectively. Ground water level contour map for January, 2006 shows the maximum drawdown in Tejgaon area; the industrial zone of the city with maximum no of privately owned deep tube wells. The upper Dupital aquifer is exploited most in this case and shows considerable fall in water table. Therefore, Tejgaon area is considered critical for future water supply conditions and subject to land settlement. The ground water contour map is provided below.

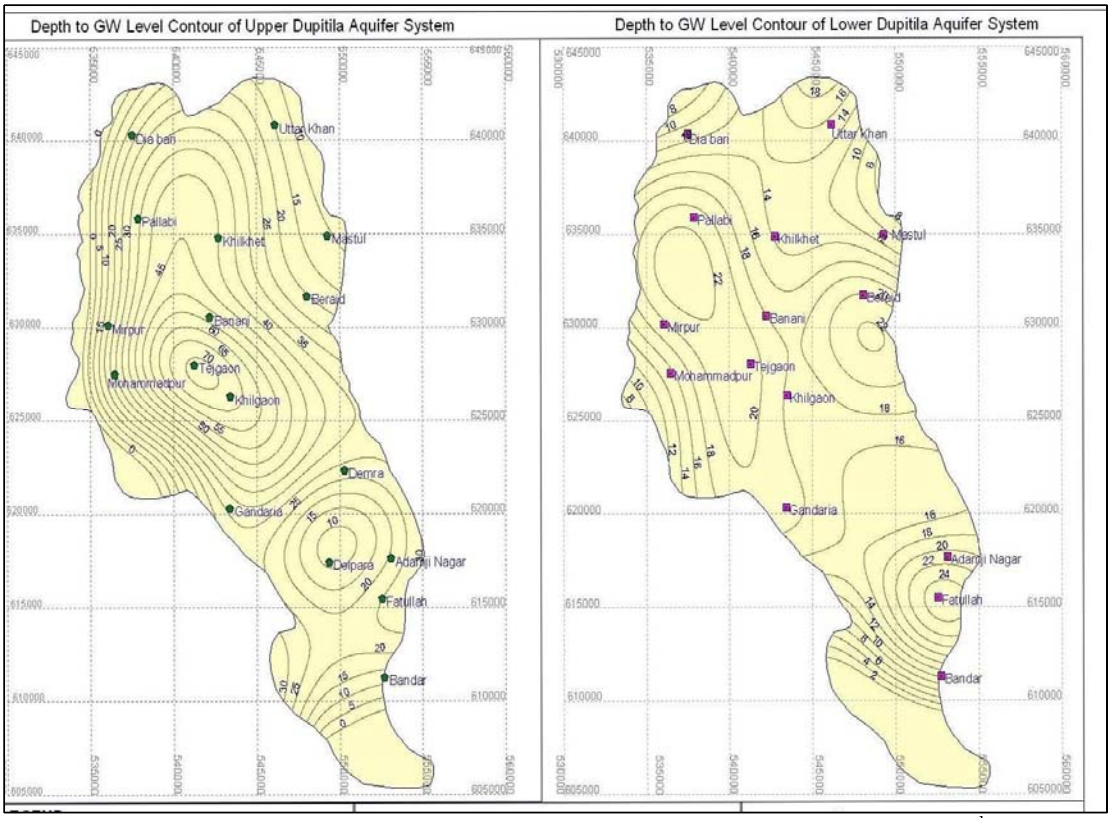

Figure 3.4 Ground Water Contour Map of aquifer system of Dhaka City on 8th Jan, 2006

Source: IWM, 2007

Water charges for Dhaka WASA jurisdiction area are different for domestic, commercial and industrial water consumers. Water tariffs for metered, non-metered and water extracted from tube-well vary. Metered water is charged for every thousand gallons or liter. Non-metered water is charged on the basis of holding per annum as % of valuation.

3.2.2 Surface water:

At present Saidabad water treatment Plant (SWTP) is supplying treated potable water. Water is being drawn from Lakhya River to the east of Dhaka City for SWTP. River water contains high level of ammonia during the dry season. Additional 225 MLD of water supply is planned which will be implemented in near future. Surface water production varies with seasonal water availability.

3.3 Data collection

3.3.1 Primary Data Sources

The study is based on primary data collected through reconnaissance survey, interviews, field observations, questionnaire survey using contingent evaluation method.

i) Reconnaissance Survey

The reconnaissance survey is carried out to revise the contingent evaluation survey questionnaire according to field situation.

ii) Field Observation

Field observation was carried out for water supply and distribution authority main offices and the study areas. The purpose behind this investigation has been to obtain a clear picture of policy practices, implementation procedures and purposes behind water allocation planning and system. Then again, the present water use for domestic and industry sectors along with metering system, water supply condition was observed.

iii) Questionnaire Survey

Questionnaire survey is conducted focusing on issues of supply satisfaction and willingness to pay of the water consumers in Dhaka City. Water supply, demand and tariff perceptions of the DWASA account holders; residential, commercial and industrial were explored. Questioning on hypothetical future or option is contingent valuation method or CVM. It involves questionnaire survey among consumers what will be their willingness to pay for water on some hypothetical options or changes in future state of water supply and service. By using CVM, random or stratified samples of individuals will be selected from study area and will be given particular water policy change scenarios.

3.3.2 Secondary Data

The secondary data and information are collected from different sources. The main sources are; Water Supply and Sewerage Authority (DWASA), and Water Resources Planning Organization (WARPO) and Bangladesh Bureau of Statistics. Publications, annual reports, project reports, statistical reports are used as secondary data.

3.3.3 Sampling:

Sample size for the field survey is calculated using following formula:

$$n = \frac{N}{1 + \left(N * e^2\right)}$$

Where, n = sample size
N = total population
e = level of precision

(Yamne, Taro, 1967)

Total number of connections are used as proxy of total population. 95% level of precision (e= 0.05) is used to finalize a total number of 400 samples of residential, commercial and industrial consumers. The details of categorization of survey sampling are shown below:

Table 3.5 Sample size of survey

Description	Residential	Commercial	Industrial	Total
Zone II	90	72	33	195
Zone III	108	86	13	207
Total	198	158	46	402

The samples for residential water consumers are collected concentrating on different types of residence. Hi-rise buildings, five storied buildings, individual housing, slum areas are investigated for meeting a wide range of people with diversified opinions about water consumption, service satisfaction and their willingness to pay. For commercial water consumers, workshops, hotels, hair salons, clinics, private universities, community centers (weddings and other event occurrence places for rent). For investing commercial water consumption in Dhaka City, seven categories of common commercial water users are identified for sample survey. In the selected areas, very few industrial water users could be discovered. Among the two survey areas, zone II has a number of industries; leather, plastic and bakery. The leather industries are questioned in a different manner as almost none of them are DWASA account holders. Their work requires unlimited amount of water which is not possible for DWASA to supply. Consequently, industries in need of 24 hour water supply have installed individual deep tube wells in their own premises and extracting about 40 to 100 liters (0.04-0.1 m^3) of water per hour.

3. 4 Data Analysis

3. 4. 1 Qualitative Statement

Qualitative statements is used to describe the current status of water sector, organization structure of pricing policy, practice and implementation status, and the operation and maintenance strategy of water distribution.

3. 4. 2 Descriptive Statistics

Descriptive statistics is the medium of describing data by distribution, central tendency and dispersion. Summary of the frequency of individual values or ranges of values for a variable can describe the distribution of data set. The central tendency of a distribution is an estimate of the "center" of a distribution of values. Mean, mode and median are used to describe central tendency of data set. For describing the spread of the values around the central tendency, range and standard deviation are used.

3. 4. 3 Weighted Average Index (WAI):

WAI is used to evaluate the responses from contingent valuation survey. The WAI is applied to measure the satisfaction parameters which are computed from field data.

Strongly Disagree	Disagree	Neutral	Agreed	Strongly Agreed
0.2	0.4	0.6	0.8	1.0

The score of such scaling is calculated with following formula (Miah, 1993).

WAI = [{fSTS (2) +fS (1) +fNe (0) +fDS (-1) +fSDS (-2)}/N]

Where,
WAI = Weighted Average Index
fSTS = Frequency of strongly agreed.
fS = Frequency of agreed
fNe = Frequency of neutral
fDS = Frequency of disagreed
fSDS = Frequency of strongly disagreed
N = Total number of observation

The responses from field survey are entered in SPSS software with featured value against each response and thus AWI are calculated.

3.4.4 Chi-square Test

Pearson's chi-square ($\chi 2$) test is a statistical non-parametric procedure whose results are evaluated by reference to the chi-square distribution. It tests null hypothesis that the frequency distribution of certain events observed in a sample is consistent with even theoretical distribution or not. The events considered must be mutually exclusive and have total probability of 1.

Pearson's chi-square is used to assess two types of comparison: tests of goodness of fit and tests of independence. A test of goodness of fit establishes whether or not an observed frequency distribution differs from a theoretical distribution. A test of independence assesses whether paired observations on two variables, expressed in a contingency table, are independent of each other. A chi-square probability of 0.05 or less is commonly interpreted by applied workers as justification for rejecting the null hypothesis that the row variable is unrelated (that is, only randomly related) to the column variable. The alternate hypothesis is not rejected when the variables have an associated relationship.

In this study, chi-square test has been used to evaluate the relation between certain parameters. Income of residential consumers and satisfaction parameters has been tested to check of potential relation between them. SPSS software (11.5) is used for performing chi-square test and other statistical analysis.

3. 4. 5 Ordinary Least-Square Regression Analysis (OLS)

SPSS version 11.5 software is used for performing regression analysis for this study. Continuous dataset with variables declared from questionnaire survey and some secondary data are used to formulate regression models.

3.4.5.1 Theoretical Concept

Linear regression is a form of regression analysis in which observational data are modeled by a function which is a linear combination of the model parameters and depends on one or more independent variables.

a) Simple Regression Analysis

Regression analysis is a statistical technique for obtaining a best fits line according to an objective statistical criterion. This line is obtained by minimizing the sum of the squared vertical deviations of each point from the regression line. The linear regression model assumes that there is a linear, or "straight line," relationship between the dependent variable and each predictor. This relationship is described in the following formula.

$$Y = a + b * X$$

,where X and Y are two observed samples and the variable X is used as the independent variable influencing dependent variable Y. vertical intercept of this equation is (a) and coefficient is (b).

The relation between these two variables is then figured out using OLS method. The objective of regression analysis uses the given values of X to get estimates of (a) which is the vertical intercept and (b) which is the slope of the line. The estimated values of (a) and (b) are obtained by minimizing the sum of the squared deviations. Thus the equations for getting estimated values of (b) and (a) are:

$$b = \frac{\sum_{t=1}^{n}(X - \bar{X})(Y - \bar{Y})}{\sum_{t=1}^{n}(X - \bar{X})^2}$$, here $\bar{X}$ and $\bar{Y}$ are the average values of X and Y variables.

$$a = \bar{Y} - b\bar{X}$$

There are a number of assumptions for regression analysis as explained here. The error term is to be normally distributed, with zero expected value or mean, with constant variance in each time period and its value in one time period is unrelated to its value in any other period. (Salvatore, 2001)

b) Multiple Regression Analysis

In multiple regressions, more than one variable is used to predict the criterion. Additional assumption for multiple regression analysis are that the number of independent or explanatory variables in the regression should be smaller than the number of observations and no perfect linear correlation among the independent variables can exist. The model can be formulated with multiple numbers of independent variables as indicated in the following equation (Salvatore, 2001).

$$Y = a + b_1 * X_1 + b_2 * X_2 + ... + b_n * X_n$$

Correlation matrix of the dependent and independent variables is used to find the coefficients of correlations between them. Values of a correlation coefficient range from –1 to 1. The sign of the coefficient indicates the direction of inter relationship, and the absolute value indicates the strength, with larger absolute values indicating stronger relationships. Values closer to 1 for two variables indicate that they are highly correlated. The correlation coefficients of the variables considered for influencing residential water consumption do not present strong relations and hence all of them are utilized for analyzing water consumption model. The next step is one way ANOVA procedure which produces a one-way analysis of variance for a quantitative dependent variable by a single factor (independent) variable. Analysis of variance is used to test the hypothesis that several means are equal.

The ANOVA table tests the acceptability of the model from a statistical perspective. While the ANOVA table is a useful test of the model's ability to explain any variation in the dependent variable, it does not directly address the strength of that relationship. The model summary table reports the strength of the relationship between the model and the dependent variable. *R*, the multiple correlation coefficients, is the linear correlation between the observed and model-predicted values of the dependent variable. Its large value indicates a strong relationship. R square, the coefficient of determination, is the squared value of the multiple correlation coefficients.

Test of Significance

Several indices can be used to examine the goodness of fit of the model. Development of a fit model will require that all the indices mentioned below exceed the criteria. Most common indices are:

a) R-squared, or coefficient of determination and adjusted R square
b) Standard Error
c) F-statistics
d) t-statistics

a) Coefficient of Determination, R^2 and adjusted R square

The model summary table reports the strength of the relationship between the model and the dependent variable. *R*, the multiple correlation coefficient, is the linear correlation between the observed and model-predicted values of the dependent variable. Its large value indicates a strong relationship. *R Square*, the coefficient of determination, is the squared value of the multiple correlation coefficient. It expresses the percentage of variation in *time* can be explained by the model of equation. The coefficient of determination, R^2 is It depends on the ratio of sum of square error from the regression model (SSE) and the sum of squares difference around the mean (SST = sum of square total). The equation is as follows

$$R^2 = 1 - \frac{SSE}{SST}$$, where $$SSE = \sum_i (y_i - \hat{y}_i)^2$$ and, $$SST = \sum_i (y_i - \bar{y})^2$$.

Incase of no variation in Y are explained by the variation in X, R^2 will be equal to zero. The value of R^2 is ranged from 0 to 1 where nearing 1 indicates a closer relationship between X and Y. In cases with cross-sectional data, the value of R^2 is often not high (Griffin, 2006)

However, the SST and SSE are not measure of the variance. To use the proportion of variances, the average the sum of square is obtained using the following formula

$$R^2_{adj} = 1 - \frac{MSE}{MST}$$

Mean square error and mean square total can be calculated using the following equations; $MSE = \frac{SSE}{(n-q)}$ and $MST = \frac{SST}{(n-1)}$ as n is the number of sample and q is the number of variables used in the model. So, the final relation for adjusted R^2 is

$$R^2_{adj} = 1 - \left(\frac{\left(1 - R^2\right)(n-1)}{n-q} \right).$$

b) Standard Error

Different test of significance of parameter are used to find out the best fit curve by regression analysis. Standard errors are important because they reflect how much sampling fluctuation a statistic will show. The standard error of a statistic depends on the sample size. In general, the larger the samples size the smaller the standard error.

$$Std.Error = \sqrt{MSE} = \sqrt{\frac{SSE}{n-q}}$$

c) F-statistics Test

Another index for goodness of fit of the model is F-statistic, using Mean square regression (MSR) and Mean square error (MSE).

$F = \frac{MSR}{MSE}$, MSR= Mean Square Regression

$$MSR = \frac{\sum_i (\hat{y}_i - \bar{y})}{q-1} = \frac{SST - SSE}{q-1}$$

F-statistics is used to test the hypothesis that the variation in the independent variables explains a significant proportion of the variation in the dependent variable. The calculated or regression value of the F-statistics is compared with the critical value from the table of the F distribution. If the calculated value exceeds the critical value, the null hypothesis at chosen level of significance is rejected which means that at chosen level of significance the coefficients of the variables are not equal to zero.

d) T-statistics test

T-statistics test is conducted to find out whether or not there is a significant relationship between the dependent and independent variables. T-calculated value is then compared with critical value of the t distribution with the degree of freedom at a chosen significance level. This test is conducted to find out whether the slope of a regression line differs significantly from 0. Following the same procedure as F-statistics, the calculated value of t-statistics is required to be higher than t-critical value to reject the null hypothesis.

3.4.5.2 Water Demand Estimation by Regression Analysis

Different determinants from literature review and site visitation are selected for developing water demand and actual water production model. The model equation for water demand and supply assessment is as follows:

Q= f (No of determinants)
= f (x_1, x_2, x_3 …, x_n)

1) Linear: $Q = b_0 + b_1 x_1 + b_2 x_2 + ... + b_n x_n$

2) Log-linear: $\ln Q = b_0 + b_1 x_1 + b_2 x_2 + ... + b_n x_n$

3) Log-log: $\ln Q = b_0 + b_1 \ln x_1 + b_2 \ln x_2 + ... + b_n \ln x_n$

Q= Dependent variable, water demand,
$x_1 + x_2 + ...x =$ Independent variables
$b_0 =$ Intercept
$b_1 + b_2 + ...b_n =$ Coefficients of the explanatory variables
(Pradhan, 2003) & (Dhungana, 2002)

Water demand model are formulated using cross-sectional and time-series data. For model development with cross-sectional data; income, household size, education level, tapped water supply hrs per day whereas for time-series data; residential water tariff, per capita income, number of residential connections and mean monthly temperature are considered for the average monthly water consumption estimation.

Fixed volumetric price per cubic meter of water as charged by DWASA is used in this analysis. The price variables are adjusted for inflations using the following formula for monthly basis where discounted value of past investment is calculated for *m* times a year of *T* years with r as rate of discount (Salvatore, 2001).

$$FV = C_0 \times \left(1 + \frac{r}{m}\right)^{m \times T}$$

GNP per capita has been used as a proxy for consumer income which has been converted to monthly per capita using inter year GNP growth rate. Average monthly water consumption data has been collected using total billed amount issued by DWASA for mentioned time periods and water tariff at that time. Data of number of connections are collected from MIS report by DWASA and monthly climate data from Bangladesh Meteorological Department centered at Dhaka.

3.4.5.3 Annual Revenue Estimation by Regression Analysis

Following the same method explained in section 3.4.4.3, annual revenue of DWASA is estimated. Several influencing parameters are identified from secondary reports and thus multiple regression model of annual revenue is formulated. Residential water tariff, commercial water tariff, revenue collection efficiency and number of connections are used to develop annual revenue model.

3.4.6 Point Expansion Method

Point expansion method is used to estimate demand or marginal benefit function by knowing a point on the demand function from before with a known price elasticity of demand. In this case, price elasticity of demand can be assumed to exogenously obtained (Griffin, 2006).

Exponential inverse demand function is adopted from Aquarius Appendix B,

$$P = a * \exp(-\frac{Q}{b})$$

(Source: Equation B.1)

The inverse demand function is thus, Q= b*(ln a-ln P), here (P, Q) is a known point in demand function and (e) is price elasticity of demand. In particular, for an exponential demand function, elasticity is expressed by the ratio of the coefficient b and the quantity demanded Q.

$$e = \frac{\delta Q / Q}{\delta P / P} = -\frac{b}{Q}$$

The coefficients of (a) and (b) can be computed using the following formula,

$$b = -e * Q$$

$$a = \frac{P}{\exp(\frac{1}{e})}$$

(Source: Equation B.8 & B.9)

3.4.7 Surplus Estimation

Inverse MB or demand curve is integrated between chosen (present or alternative) price and maximum willingness to pay to get consumer surplus. The same price is replaced in marginal benefit curve and thus corresponding changed quantity is calculated. Placing this changed quantity in marginal cost curve results in the changed price. The inverse marginal cost curve is thus integrated between 0 and the newly calculated price level. This indicates some loss in the process which is considered as dead weight loss.

Price can be efficient in playing major roles in a market. Prices are a signal to producers about the return to producing another unit. At the same time, prices are a signal to consumers about the cost of consuming another unit. It is this signaling role of prices that insures that certain amounts get produced. Prices also play a distributive role in determining total surplus or maximized net benefit for consumers and producers. Social or total surplus is thus estimated by summing up consumer and producer surplus at the same price. Change in market price results in change in total surplus which indicates some loss or gain for consumers, producers and in some cases for Government. Microsoft Excel is used fore calculations of surplus.

The amount the consumer is willing to pay for a quantity Q is the area under the demand curve from 0 to Q. In this case, total surplus is calculated focusing on price as the major role player and inverse demand and supply curve are used. Marginal benefit curves for residential and commercial consumers are used from section 5.1.3.2 and section 5.2.3.2 of chapter V.

CHAPTER IV

Performance Evaluation of DWASA

Investigation of Dhaka City water supply features entails the analysis of operational, financial and service performance indicators. Various standards and different criteria efficiency are analyzed from operational, financial and tariff structure perspectives. Water production per capita, water supply per capita, system loss/ NRW, source of water, personnel per 1000 connection, supply area coverage are all to be analyzed with time and space.

4.1 General Features

Table 4.1 Water Supply Features of DWASA

Sl. No	Supply Features	Unit	Value
1	Total production	Mm^3/day	1.415
2	Annual Production	Mm^3	516.9
3	Annual surface water production	Mm^3	76
4	Annual ground water production	Mm^3	440
5	Deep tube well	No	465
6	Surface water treatment plant	No	3
7	Metered Connection	No	160458
8	Non- Metered Connection	No	72064
9	Public Standpipes	No	1643
10	Water line	Km.	2577.82
11	Service Area	Sq. Km.	470
12	Population served	Million	7.7
13	Total number of personnel	No	3735
14	System Loss	%	35
15	Treatment medium	-	Chlorine

Source: DWASA, 2007

There are several public stand pipes which serves the urban poor people unable to afford water tariff. 15% of the total population of Dhaka City is identified living in slum area (ADB, 2006). DWASA has these stand pipes in operation in three zones; Zone I, II and VII.

4.1.1 Water Supply Source

Table 4.2 Water Supply Production and Source

Source	Production capacity in Mm^3/day	Actual Production		Source wise % of Production
		Mm^3/day	% of Capacity	
GW	1.541	1.21	78.1	84.83
SW	0.297	0.212	71.14	15.17
Total	1.838	1.415	77	100.00

Note: GW= Ground water, SW= Surface water Source: DWASA, 2007

4.1.2 Water connections

The total number of accounts for all categories of consumers is 237975. This number only represents the legal connections accounted before June, 2007. Domestic water account is 96% of the total accounts. These connections represent two types of connections; metered and non-metered. About 67% of the total number of connections is metered which are charged volumetrically according to consumption. The rate of tariff for the non-metered connections is in % of valuation holdings per annum; certain percentage on the yearly tax for the property is paid for water supply with non-metered connection. At present, it is attempted to bring every connection under metering condition.

Table 4.3 Distribution of Accounts based on Category

Zone	Domestic Account	Commercial Account	Industrial Account	Community Account	Offices Account	Total
I	49070	948	257	180	173	50628
II	22327	97	128	71		22623
III	26267	838	52	68	77	27302
IV	51423	717	224	308	34	52706
V	43359	1063	855	137	355	45769
VI	26594	874	106	89	6	27669
VII	9416	406	44	28	11	9905
Total	228456	4943	1666	881	656	237975

Source: DWASA, 2007

In the year of 2006-2007, 12500 water connections were installed of which 90% were metered. The current metering situation for the seven MOD zones is represented by figure 4.1. At present, zone III has more than 80% of metered connection of its total number of connections whereas zone III has more than 50% of non-metered connection. All in all, 70% (160458) of the total number of connections (232522) are metered.

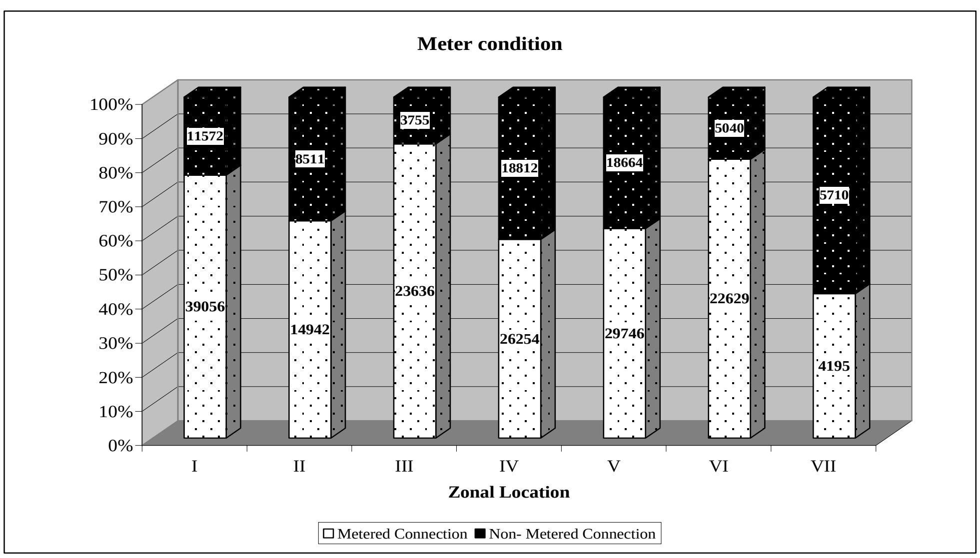

Figure 4.1 Metering of MOD zones of Dhaka City (Source: DWASA, 2007).

4.1.3 Supply Coverage

At present, DWASA supplies water to about 7.7 million people covering 470 sq. km area. The total pipeline is about 2500 km. Network density is total km of pipe line by total service area in square km. For DWASA, network density is 5.22 km. DWASA serves approximately 65% of the total population (ADB, 2006).

4.2 Operational Indicator Analysis

Operational indicators are useful in assessing the performance of water and waste-water utilities. Water consumption, distribution system, % of unaccounted for water (UFW), personnel and other miscellaneous indicators are calculated to evaluate operational efficiency of DWASA.

4.2.1 Unit Distribution and Consumption

Unit consumption has been calculated for metered consumptions. Unit water consumption according to distribution from DWASA in cubic meter per connection is exhibited in table 4.4. Daily distribution per connection has an increasing trend from year 2000 to present.

Table 4.4 Unit water Distribution per Connection

Year	Annual Water Production in Mcm	System Loss in %	Actual annual water distribution in Mcm	No of connections	Annual distribution in m3 per connection	Daily Distribution in m3 per connection
1999-2000	386.22	50	193.11	184503	1046.650	2.86
2000-2001	414.14	56	182.22	191087	953.619	2.61
2001-2002	444.06	57	190.94	202894	941.111	2.57
2002-2003	493.54	55	222.09	212543	1044.936	2.86
2003-2004	516.04	49	263.19	217003	1212.813	3.32
2004-2005	527.31	44	295.29	225489	1309.575	3.58
2005-2006	514.06	39	313.58	232907	1346.381	3.68
2006-2007	516.92	35	335.99	243477	1412	3.86

Source: DWASA, 2007

Slow-moving management systems along with corruption of staffs of DWASA are responsible for huge system loss. Some accounts are not registered and connections have no trace of account due to lack of coordination among technical, accounting and management departments.

DWASA follows the standard requirement or design water requirement of 0.16 m^3/c/d. Monthly variation of water capita is calculated with different population figures for 2006 and 2007 using monthly data. Population served by DWASA served area for 2006 is obtained from ADB report on Dhaka water supply project and for 2007 it is obtained from IWM report of Resource Assessment and Monitoring of water supply sources for Dhaka City.

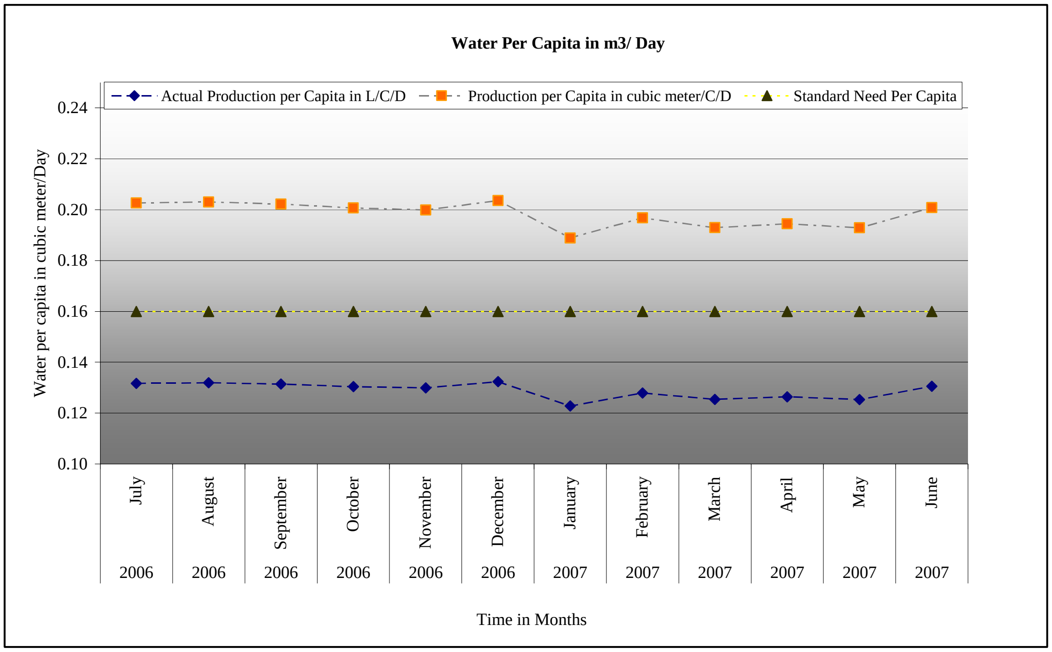

Figure 4.2 Water production per capita (Source: DWASA, 2007).

Actual production per capita has been considered with a 35% system loss for the period of 2006-2007. Maximum available water per capita per day is 0.132 m^3 and minimum is 0.122 m^3. The difference for water per capita for production, actual production and standard values is observed from figure 4.2. There is an average of 0.031 m^3 of insufficiency of water. Minimum water production is observed in the dry season. It is reasoned due to seasonal unavailability as there are minimum amount of precipitation in dry season.

4.2.2 Distribution of water consumption

Water consumption distribution is calculated for three major consuming sectors with two different parameters; % of total consumption and % of total connections.

Table 4.5 Distribution of water consumption

Description	Residential	Commercial	Industrial
% of total consumption	99.29	0.64	0.08
% of total connections	97.19	2.10	0.71

Source: DWASA, 2007

It is thus established that residential consumers consume major portion of total water production. Non-residential consumption only comprises of 1% of the total consumption. The connection accounts also confirm that 97% accounts are residential whereas only 3% belongs to non-residential consumers. It is found that commercial and industrial water demand is 10% of total demand (ADB, 2006 and DWASA, 2007) which confirms that DWASA is currently supplying only 1% of total water demanded by non-residential consumers.

4.2.3 Length of water distribution system

Length of the water distribution pipe system is represented as a function of number of connections. It is observed that although, number of connection and length of water line both increased with time, unit length has decreased as length of water line has not increased proportionately with number of connections.

Table 4.6 Unit length of Water Distribution System

Year	Length of water line in Km	Length of water line in m	No of Water Connection	Unit Length (meters/connection)
2000	2080.32	2080320	184503	11.28
2001	2127.48	2127480	191087	11.13
2002	2127.48	2127480	202894	10.49
2003	2358.86	2358860	212543	11.10
2004	2475.62	2475620	217003	11.41
2005	2474.43	2474430	222072	11.14
2006	2520.91	2520910	225489	11.18
2007	2533.73	2533730	243477	10.41

Source: DWASA, 2007

4.2.4 Pipe Breaks or Leaks

Number of pipe breaks per year per 100 kilometers of pipes in the water system is indicative of problems related to materials, installation, age, soil conditions, traffic and maintenance. As, data for pipe breaks as function of material, age and relevant information are not available, detailed investigation has not been possible for this matter. Breaks or leaks for year 2007 per 100 km are calculated in table 4.7.

Table 4.7 Breaks/Leaks in one year

Year	Length of water line in Km	Breaks	Pipe Breaks/100 km/ year
2006- 2007	2533.73	275	10.85

Source: DWASA, 2007

4.2.5 Unaccounted for Water (UFW)

A major concern about operations of a water utility is the level of UFW. UFW reflects the difference between the volume of water delivered to the distribution system and the water sold. The level of UFW is considered a good proxy for the overall efficiency of operations of a water utility (WB, 1999).

There are usually two components of System Loss. The first part is accounted for physical losses and second one for administrative losses. Physical losses are inevitable for any water supply network, but administrative losses are due to illegal connection, water meter tampering and other such reasons.

Table 4.8 Zonal Ground Water Production Capacity

Zone	Active DTW No	Public Standpipes	Intended Water Production in Mcm/day	Actual Water Production in Mcm/day	Distribution in % of production in Mcm
Zone I	78	250	0.2792	0.235	84.17
Zone II	42	259	0.1925	0.164	85.19
Zone III	72	0	0.25	0.23	92.00
Zone IV	97	0	0.2454	0.227	92.50
Zone V	97	0	0.3315	0.3	90.50
Zone VI	73	0	0.2225	0.208	93.48
Zone VII	16	864	0.0865	0.058	67.05
Total	475	1373	1.61	1.42	88.45

Source: DWASA, 2007

The zonal water distribution calculation in terms of % of production capacity produces an average of 11% loss of water in the process whereas the yearly system loss data shows a change from 50% to 35% in last 8 years. Figure 4.3 presents trend of system loss from year 2000 to 2007. The leakage component can be measured by water lost per kilometer of distribution and as water lost per connection (ADB, 2003)

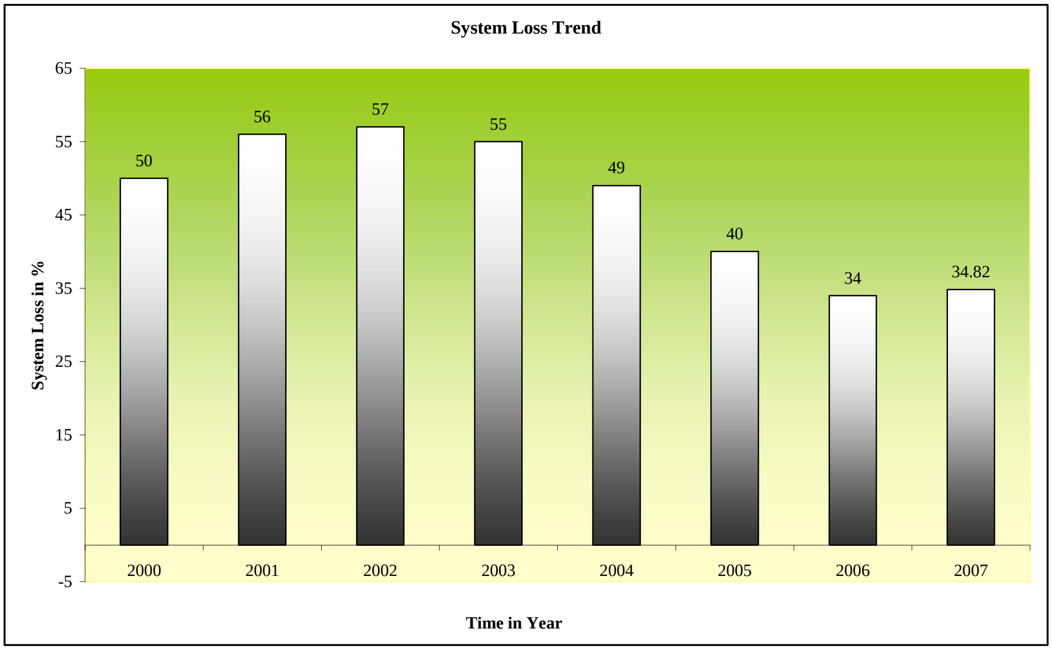

Figure 4.3 System loss trend (Source: DWASA, 2007).

NRW or Non Revenue Water is another term for unaccounted for water (UFW). It is being safely assumed that administrative loss is about 25% for DWASA. In total, about 0.36 cubic meters of water is going to astray per day which in turn is affecting water demand and consumer revenue at the same time. UFW reflects management of water utility and well-managed utility should not have a ratio of more than 20% for that (WB, 1999). It is thus established that system loss for DWASA is required to lessen by dealing with administrative and physical losses at the same time.

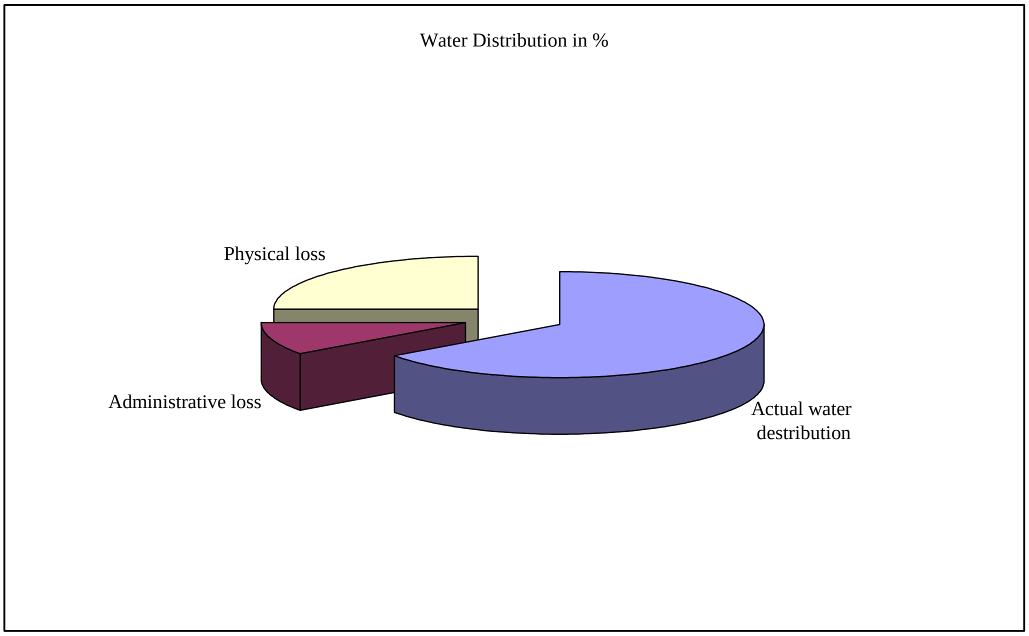

Figure 4.4 Water distribution components (Source: DWASA, 2007).

4.2.6 Number of staff

Number of staff is assessed from the perspectives of water connections, water distribution, and supply pipeline length.

Table 4.9 Staff Ratio for DWASA

Year	Total Number of Personnel	Staff/1000 connection	km/staff	m3[1000]/staff
2000	3843	20.83	0.54	58.17
2001	3855	20.17	0.55	110.85
2002	3855	19.00	0.55	132.23
2003	3799	17.87	0.62	133.62
2004	3684	16.98	0.67	139.96
2005	3730	16.54	0.68	141.05
2006	3740	16.06	0.67	148.74
2007	3735	15.34	0.68	156.67

Source: DWASA, 2007

Any water utility for smooth and efficient running requires around two staff per every 1,000 connections in that utility (McIntosh, 2003). Yearly data for DWASA shows that number of personnel including staff and officers compared with every 1000 connections reduced from 21 to 15 in last 7 years. This same pattern follows for system loss as well. It can be seen from figure 4.3 that system loss descended about 15% in the last 7 years following the same pattern of staff ratio. This indicates that administrative loss may be an influencing factor at the back of water distribution and productivity limitations of DWASA.

4.2.7 Staff Composition

Table 4.10 Staff Composition of DWASA

		Composition in %		
Year	Personnel	Class I Officer	Class II Officer	Staff
2000	3843	4.42	5.28	90.29
2001	3855	4.31	5.19	90.51
2002	3855	4.31	5.19	90.51
2003	3799	4.21	5.16	90.63
2004	3684	3.99	5.10	90.91
2005	3730	4.13	4.69	91.18
2006	3740	4.30	4.63	91.07
2007	3735	4.20	4.63	91.16

Source: DWASA, 2007

Distribution of members of staff is uneven as only 10% of total work force comprises of designers, planners and engineers. Then again, staff Productivity Index is very high for running an efficient water utility. System loss is following the same pattern of reduction as of SPI. So, there is considerable opportunity for DWASA to enhance quality of service by changing staff composition in number and composition.

4.2.8 Training Program

Table 4.11 Training Programs and Courses in 2006-2007

Sl No	Category	Training Course	Trainee
1	Foreign	Master Program in Water Management and Public Policy	2
2	Local	English language course	2
		Personal computer troubleshooting	3
		Public procurement management	1
3	In house	Pump operation	20

Source: DWASA, 2007

In last fiscal year (2006-2007) several training courses have been arranged which were attended by 28 staffs (1% of total personnel). There is no annual training procedure or performance evaluation system for staff of DWASA. In 1980, DWASA established one training center which is currently lacking human and financial resources and considered not effective (ADB, 2006).

4.2.9 Meter Maintenance and Replacement Practice

Table 4.12: Meter Maintenance and Replacement

Year	Conversion		Replacement	
2006-2007	1380		532	
Month	Tested	Tampered	Repaired	Not repairable
June, 2007	350	90	75	185

Source: DWASA, 2007

It has been found out that a number of meters are tampered every month. Out of 350 meters were tested 26% were found tampered. It clearly indicates that meter tampering is a reason of administrative loss of DWASA. Non-metered connections are being converted to metered connection every month to bring every water connection under metering system.

4.3 Financial Indicator Analysis

Financial efficiency and operational ratios are assessed with several indicators; working ratio, operating ratio, accounts receivable/collection period, personnel cost, staff productivity index, O & M cost components, unit operation cost and revenue.

4.3.1 Working Ratio & Operational Ratio:

Working ratio (WR) is the ratio of operating costs to operating revenues. Operating costs in this ratio exclude depreciation and interest payments (but no debt service payments), a key difference with the Operating Ratio (OR) that includes these costs. Operating revenues remain the same for both ratios (WB, 1999). For DWASA, operating revenue consists of water bill collection, water sales by vehicle, connection fee, sale of meter, rent of DWASA building to another company and DTW license or renewal fees.

Table 4.13 Working Ratio of DWASA

Year	Power Cost in M Tk.	Chemicals cost in MTk.	Repair & Maintenance cost in MTk.	Administrative Cost in MTk.	Bad Debts in MTk.	Total Operation Cost in MTk.	Total Revenue in MTk.	WR
2004 - 2005	1045.98	52.95	204.26	521.45	125.09	1949.73	2146.76	0.908
2005 - 2006	1130.58	99.7	251.87	703.56	139.3	2325.01	2430.28	0.957

Source: DWASA, 2007

Table 4.14 Operating Ratio, Average Tariff and Unit Production cost

Year	Actual annual water distribution in Mcm	Total O & M Cost in MTk	Total Revenue in MTk	Unit Production Cost (Tk/m3)	Average Tariff in Tk/m3	OR
2000-2001	182.22	2373.46	1524.463	5.73	3.30	1.73
2001-2002	190.94	2571.03	1756.98	5.79	3.56	1.63
2002-2003	222.09	2748.40	1961.325	5.57	3.61	1.54
2003-2004	263.183	3019.60	2256.527	5.85	4.04	1.45
2004-2005	291.39	2680.63	2146.762	5.08	4.74	1.07
2005-2006	344.927	3083.27	2430.289	6.00	5.49	1.09
2006-2007	312.33	3419.65	2898	7.17	6.32	1.13

Source: DWASA, 2007

Average tariff indicates financial efficiency of any water utility. It is an indicator of recovering operational cost with revenues from tariff. Average tariff of DWASA has increased from 3.39 Tk to 6.32 Tk in last 8 years of time. Unit production cost is estimated from total cost and actual annual water distribution. Actual annual distribution has been calculated after deducting system loss during distribution. Total cost data is collected from DWASA for fiscal year 2004-05 and 2005-06. Cost data for other fiscal years are derived by interpolation. Average tariff is considerably lower than unit production cost which points toward financial inefficiency of DWASA.

Sound financial management requires WR to be well below 1 (WB, 1999). Here, in this case, WR is nearing 1 which indicates some opportunity for financial improvement. Operating cost excluding depreciation and debt payment is almost same as operating revenue. OR is the ratio of operating costs to operating revenues. In this case, operational costs include all the expenses together with depreciation and interest costs (but no debt service payments). Sound financial management requires OR to be less than 1 which is more than 1 for DWASA as seen table 4.14. This value again indicates that operating revenue is not able to recover O & M cost which is deferring policy of DWASA to cover their O & M cost and some of capital expenditures from operational revenue.

4.3.2 Accounts Receivable/Collection Period (CP)

This indicator, expressed in month equivalent of sales, is the ratio between the year-end accounts receivable and operating revenues, multiplied by 12. When the CP is increasing, cash flow of a company can be in jeopardy. Poor collection efficiency is mostly blamed on consumers and especially for public sector agencies. However, the water utility can be at fault for delayed and faulty billings, inadequate responses to consumer's queries on billings, and a lukewarm effort to collect overdue accounts. A common factor found among the utilities with poor collection efficiency is the lack of clear policy to promote and enforce prompt payment (like disconnecting the service to consumers with arrears of more than 2 to 3 months) (ADB, 1999). Performance evaluation of staffs on regular basis comparing it to financial condition of utility can work as incentive to improve the later one.

Table 4.15 CP and Revenue Collection Efficiency

Year	Year end accounts receivable in Million Tk.	Total Revenue in Million Tk	Accounts Receivable/Collection Period*12	Billed in Million Tk.	Collected in Million Tk.	Collection Efficiency
1999-2000	1078.48	1397.21	9.26	1308.83	962.31	73.52
2000-2001	1147.31	1524.463	9.03	1368.75	1273.6	93.05
2001-2002	1438.97	1756.98	9.83	1580.25	1288.82	81.56
2002-2003	1840.57	1961.325	11.26	1779.78	1378.2	77.44
2003-2004	2242.7	2256.527	11.93	2085.61	1683.48	80.72
2004-2005	2757.37	2146.762	15.41	2501.66	1991.46	79.61
2005-2006	3302.67	2430.289	16.31	2832.58	2275.76	80.34
2006-2007	3614.47	2898	14.97	3014.07	2709.32	89.89

Source: DWASA, 2007

Revenue collection efficiency of 100% indicates that whatever amount is billed is entirely collected. In the case of DWASA, this value is on average about 80% with 14 months of receivable amount in month equivalent arrear. It can be further observed that targeted billing and actual billing are not the same. About 90% water consumers of both Govt zones and non-government zones are billed. After that, about 80% of the total bill gets collected which refers around 70% of revenue collection efficiency instead of 80%. At present, about 240.7 Million Tk and 3366.71 million Tk are receivable from Govt and non-government respectively. There may be several factors behind slow revenue collection efficiency. Regular updating of database for duplicate, demolished accounts can prevent this situation and performance based management policy may promote higher collection leading toward sound management of DWASA.

4.3.3 Staff Productivity Index (SPI)

This ratio is an important measure of the efficiency of a water and/or sewerage utility. It relates number of staff with number of connections. As a guideline, it appears that a SPI of less than 4 is considered adequate but still in need of improvement (ADB, 1999). Then again, a ratio in between 3 to 7 is considered acceptable (McIntosh, 2003) According to world bank reports, ratio of less than 5 indicates higher efficiency and sound management of water utility (WB, 1999)

It is an important factor that reduction in the SPI ratio does not ensure increase in efficiency. Expenditures on personnel are another important parameter to consider for analyzing staff productivity (personnel costs as a % of operational costs) (ADB, 1999). Anyhow, SPI of DWASA is considerably higher than defined for a well managed utility. This may be helpful for understanding high system loss of DWASA.

Table 4.16 Staff Productivity Index

Year	Total Number of Personnel	Total no of Water Connection	Staff Productivity Index (SPI)
1999-2000	3843	184503	20.83
2000-2001	3855	191087	20.17
2001-2002	3855	202894	19.00
2002-2003	3799	212543	17.87
2003-2004	3684	217003	16.98
2004-2005	3730	225489	16.54
2005-2006	3740	232907	16.06
2006-2007	3735	243477	15.34

Source: DWASA, 2007

4.3.4 O & M Cost of water supply

Operation and maintenance cost is calculated with several cost components. Power/ electricity take about 35-40 % of the total cost of O & M. Administrative costs takes about 15-20% of the share of the total cost.

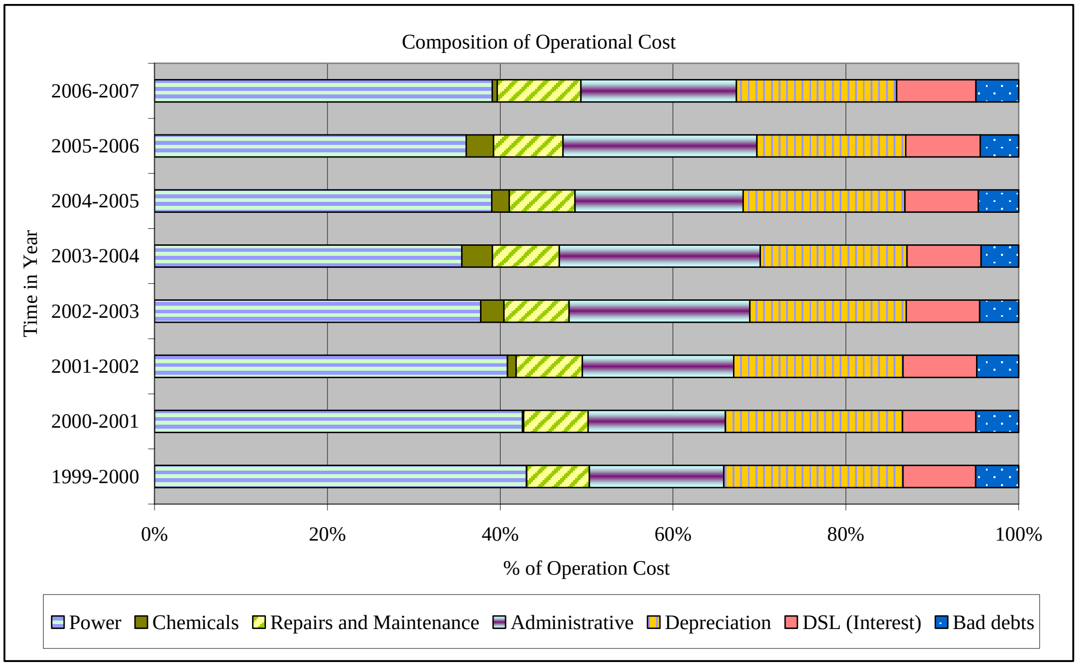

Figure 4.5 Components of O & M cost **(**Source: DWASA, 2007)**.**

Table 4.17 Range of Operation and Maintenance Cost

O & M Cost composition	Power	Chemicals	Repairs and Maintenance	Administrative	Depreciation	DSL (Interest)	Bad debts
Min	34.88	0.02	7.00	15.04	16.55	8.12	4.41
Max	41.60	3.69	8.65	24.23	20.04	8.93	4.82
Avg	38.54	1.66	7.73	18.90	18.46	8.46	4.63

Source: DWASA, 2007

Operation expenditures of DWASA are to be financed by its own revenues. Capital expenditures are party financed out of DWASA own revenues and party out of the Annual Development Plan (ADP) allocations. The funding of ADP is supported by Government funds as loan and foreign borrowings in the form of multilateral and bilateral financing. Government fund is hardly paid back and the loans from international development organizations are mostly outstanding as regular pay back was delayed. In brief, DWASA is encountering a deficit of 95 Million Tk as of June, 2007, (DWASA, 2007). Water distribution cost and water tariff for 2004-2005 and 2005-2006 is demonstrated below:

Table 4.18 O & M Cost and Revenue per 1000 Connection

Year	Total Expenditure in Million	Annual Production in MLD	System Loss in %	Total Distribution in ML	Revenue per 1000 connection in M Taka	O & M cost per 1000 connection in M Taka
2003-2004	3083.26	565454.35	38.64	346962.79	9.52	11.89
2004-2005	2680.63	520354.95	43.97	291554.88	10.43	13.24

Source: DWASA, 2007

4.3.5 Personnel Cost

Personnel costs are expressed as ratio to total operating costs (depreciation and debt service excluded). Depreciation and debt service are excluded due to lack of uniformity in treating revaluation of fixed assets and to facilitate comparison of utilities with and without debt service obligations (WB, 1999).

Table 4.19 Personnel Cost in % of Total Operation Cost.

Year	Power Cost in Million Tk.	Chemicals Cost in Million Tk.	Administrative Expenses in M Tk.	Repair & Maintenance in M Tk.	Total Operation Cost in M Tk.	Personnel Cost in % of Operation Cost
2004-2005	1045.98	52.95	521.45	204.26	1824.64	28.58
2005-2006	1130.58	99.7	703.56	251.87	2185.71	32.19

Source: DWASA, 2007

For DWASA, personnel cost is about 30% of total O & M cost which is the second highest component of total operation and maintenance cost.

4.3.6 Unit Operational Cost (UOC)

Unit operational cost (operational costs /m^3 produced) is calculated in two different currencies (Tk. /m^3 and \$/ m^3). Unit operational cost is about 0.05 \$/ m^3 representing data from year 2000 which is near to the ground or insignificant.

Table 4.20 Unit Operational Cost

Year	Water Supplied in Mcm	Total Operational Cost in M Tk	Total Operational Cost in Million $	Operational Cost/cm in Tk/cm	Operational Cost/cm in $/cm
1999-2000	386.22	1368.04	19.5435	3.54	0.0506
2000-2001	414.15	1521.10	21.7301	3.67	0.0525
2001-2002	444.06	1756.01	25.0859	3.95	0.0565
2002-2003	493.54	1952.01	27.8858	3.96	0.0565
2003-2004	516.05	2228.49	31.8355	4.32	0.0617
2004-2005	520.36	2680.60	38.2943	5.15	0.0736
2005-2006	565.45	3083.26	44.0466	5.45	0.0779
2006-2007	480.51	2344.13	33.4876	4.88	0.0697

Source: DWASA, 2007

4.4 Policy Structure of DWASA

DWASA was established in 1963 as a public utility under the Ministry of Local Government, Rural Development and Co-operative, in charge of providing water supply and sewerage services in the Metropolitan area of Dhaka. The organ gram of DWASA elucidates the role of DWASA board which has 11 members including Chairman and Vice Chairman. In 1996, the WASA act was amended in favor of DWASA to have the benefit of autonomy to adjust or impose water tariffs up to a maximum of 5% only in case of increase in power cost and inflation (Ali, 2006).

Water cost per cubic meter is assessed for operation and maintenance cost. Production costs of ground water and surface water are computed including system loss. Thus, total cost is divided by actual distribution quantity to get selling cost which neglects actual production cost. Water price is increased on the basis of inflation, power cost adjustment and administrative costs at some times (Tariff rate, sheet 1, Ac-2).

DWASA has decentralized policy for maintenance, operation and distribution of water among consumers. Seven zonal offices exist in Dhaka City apart from the Head office. For every zone, there is one operation and maintenance office and one revenue office for acting on the billing and collection activities. These two offices are liable to head office for their actions but, mutual cooperation and integrated team work seems to be absent reflecting billing of 14 months as receivable for the year 2007. Besides, service delivery varies across zones. Year wise system loss for DWASA is due to both technical and administrative reasons. The reasons are identified as insufficient maintenance, fraud and corruption by staffs and officials, poor quality of water supply network materials. Absence of training facilities and performance motivating incentives produce poor quality human resources both at technical and administrative level. Decentralized service quality of DWASA is observed from table 4.22 where system losses over the years for MOD zones are displayed.

Table 4.21 System Loss trend

Year	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	Average
Zone I	64.25	56.45	47.89	39.42	41.51	49.90
Zone II	73.60	69.81	60.05	48.47	45.08	59.40
Zone III	53.36	40.71	25.95	23.52	23.98	33.50
Zone IV	55.32	47.61	32.10	26.90	28.13	38.01
Zone V	36.02	36.59	32.77	26.65	29.62	32.33
Zone VI	50.29	44.76	43.43	37.99	35.40	42.37
Zone VII	52.31	57.82	65.62	67.55	73.89	63.44
Average	55.02	50.54	43.97	38.64	39.66	45.57

Source: DWASA, 2007

4.5 Water Tariff Structure

Tariffs are to encourage efficiency in the use of limited resources and also to make water supply and sanitation services affordable by the poor. Combination of all these objectives remains an elusive task. Water tariff of DWASA is flat based on volumetric charges (related to consumption). Water tariff is different for four type of users; residential, community, commercial and industrial. Water tariff for domestic and community water users is Tk. 5500 per cubic meter. The rate is 3 times higher for commercial and industrial water consumers. At present, the tariff of commercial and industrial water consumers is Tk. 1825 per cubic meter.

It has been found that in the period of 1982-1985, water tariff has increased about 25% for domestic and commercial consumers at the same time. After that, change of water tariff has decreased and settled at 5% increase for every year since 1998. The explanation for this 5% increase is explained in section 4.5.

Table 4.22 Present value of past tariff

Year	Quantity in thousand cubic meter	Residential water Tariff/m3	Commercial water Tariff/m3	Inflation in %	Discounted residential water tariff/m3	Discounted commercial water tariff/m3
2000	386220	4130	12750	5.80	6298.40	19441.94
2001	414146	4300	13390	6.20	6173.99	19223.58
2002	444060	4500	14000	3.10	6083.13	18923.71
2003	493542	4750	15000	5.60	6045.40	19089.47
2004	516047	5000	15750	6.00	5991.27	18871.54
2005	527312	5250	16540	7.00	5922.77	18658.93
2006	514068	5250	17500	7.20	5576.25	18587.19
2007	516918	5500	18250	8.80	5500.00	18250.00

Source: DWASA, 2007

Table 4.21 clearly demonstrates effect of inflation on change of water tariff. It seems that the increasing trend of water tariff over the years is caused by inflation rather than increasing cost of DWASA.

4.6 Summary of Results

DWASA is responsible for water supply and sewerage for Dhaka City dwellers. This is a Government organization which is hugely supported by subsidy and other donor funding. Water consumers are charged to recover operation and maintenance cost of DWASA which is not happening at this moment. This water utility has limited authority over fixing water tariff with provision of increasing tariff due to increase in personnel cost and power cost. DWASA has the record of 35% of system loss which results in water shortage for consumers. At present, DWASA has over 3735 no of employees and Staff Productivity Index exceeds the accepted standard using all means (staff/1000 connection, km/staff, m3 in 1000/staff). Lastly, DWASA is not being able to recover targeted operation and maintenance cost and running with 14.95 equivalent months of billing as arrears. The indicators analyzed in this chapter are presented below for the year 2007.

Table 4.23 Summarized Results of Evaluation Indicators

Sl. No	Performance Evaluation Indicators	Value
1.	Network Density in Km.	5.22
2.	Distribution m3/connection/day	9.78
3.	Pipe Breaks/100 km/ year	10.85
4.	Staff Productivity Index	15.34
5.	Operational Cost/cubic meter in Tk/cm	4.88
6.	Revenue Collection Efficiency in %	89.89
7.	Working Ratio	0.95
8.	Unit Production Cost (Tk/m3)	7.17
9.	Average Tariff in Tk/m3	6.32
10	Operating Ratio	1.13
11	Receivable equivalent to months	14.97

Source: DWASA, 2007

CHAPTER V

Water Consumer Profile of Dhaka City

In this chapter, water consumer profile of Dhaka City is explored. The survey areas represent South-west (Buriganga Riverside) to Mid-southern part of Dhaka City. These two parts hold major share of domestic water users with different living style and land use pattern. Consumer profiles are investigated with survey data of three categories; general, service satisfaction and willingness to pay.

Three distinctive categories of water consumers are identified in Dhaka City. The most prevailing category is domestic/community. Discussion on consumption pattern for DWASA in chapter IV demonstrates majority of domestic consumers which is about 99% of all the legal account holders. Commercial and industrial consumers are the rest of the account holders. For understanding water consumer profile of Dhaka City, a stratified sample survey was conducted focusing on domestic, commercial and industrial consumers from November to December, 2007. About 500 sample data were collected. Residential consumers were categorized by different residence types from kaccha, semi-pucca, and one-storied household to multi-storied household representing income level of the consumers. Commercial consumers were categorized according to their business types; workshop, hospital/clinic, hotel/restaurant, hair salon, community center and others. Sampling with stratified categories is explained here with table 5.1. In the selected areas, very few industrial water users could be discovered. Among the two survey areas, zone II has some industries namely leather, plastic and bakery. The leather industries are questioned in a different manner as almost none of them are DWASA account holders. Their work requires unlimited amount of water which is not possible for DWASA to supply for 24 hours of a day. In this regard, they have individual deep tube wells in their own premises for 24 hr water supply which means about withdrawal of 15-20 gallons or 0.06-0.75 cubic meter per hour. At present, it is ruled by Bangladesh Government to shut down power one day a week to discourage industries to continue 7 days a week and promote power saving. But for leather industries, use of generator keeps the work going with non-stop water withdrawal using deep tube well.

Table 5.1 Residential and Commercial Consumer Survey Sampling

Sl No	Residential Consumer Type	Frequency	Percent	Commercial Consumer Type	Frequency	Percent
1	Kaccha	24	12	Workshop	45	26.63
2	Semi pucca	34	17	Hotel/restaurant	25	14.79
3	One storied	58	29	Salon	29	17.16
4	Multi storied	82	41	Hospital/ clinic	22	13.02
5	Missing		1	Community Center	20	11.83
6				Others	28	16.57
	Total	198	100	Total	169	100

Source: Survey, 2007

5.1 Residential/Domestic Consumers

In total, 198 residential consumers are surveyed. 85% of the respondents out of 198 were male and they are the head of household. Interviewees were asked questions to identify their satisfaction level and willingness to pay or water demand circumstances for present and future.

Several observations are made during this survey. People are relaxed giving feedbacks about their problems with water availability but they prefer to avoid questions on their water bill and other financial questions. More than 50% of the people are not aware of their accurate monthly water bill figure and some are not even aware if they are paying for piped water supply of not. Most of the residential consumers are living in rented house and they pay their landlord monthly rent which includes water and sewerage bill. Although, tenants pay their individual electricity bill according to their real consumption but, most of them are unaware of their monthly water consumption or any change in water tariff established by DWASA. Most of the buildings have one water meter which may have any number of apartments and tenants. The total bill gets distributed among all residents and thus people are less concerned about the relationship between consumption and water bill.

For lower income group people, who are presently residing at rented house, water bill is not any of their concern but their landlords. When they are not getting enough piped water supply, they bring water from local mosque, public stand pipes, and neighbor houses or pump houses. For the richer suburbs area, water availability is almost never a problem. But, incase of emergency and other problems, they prefer to buy mineral water as secondary water source. One interesting observation has been made that for very rich and very poor people the responses for questions on willingness to pay regarding 10%, 25% and 50% increase in water tariff rate were very much similar. Rich people are not interested in lessending their water consumption and poor people responded that they can't reduce their water use any lower than present time. In any case, DWASA is the only piped water supply organization in Dhaka City and people are of the opinion that they are compelled to pay whatever DWASA charges for water. A lot of people are interested to pay 10% or 25% more of present water tariff to get better water supply in terms of quantity and quality.

General statistics of surveyed residential consumers are presented below and later on DWASA service efficiency from consumers' perspectives are explained using analytical tools.

5.1.1 General Background

General background information was collected from the interviewees to learn about their socio-economic conditions. Different categorical questions were asked and some answers are taken as ordinal data as people are reluctant to disclose their exact income and age. People from different background with varied age, income level, occupation and education level were interviewed to get the complete picture of consumer profile of Dhaka City. 43% of the total interviewee was of the age group of 31-45 years. In some cases, interviewee was of 14/15 years old but delivered knowledgeable responses for this survey.

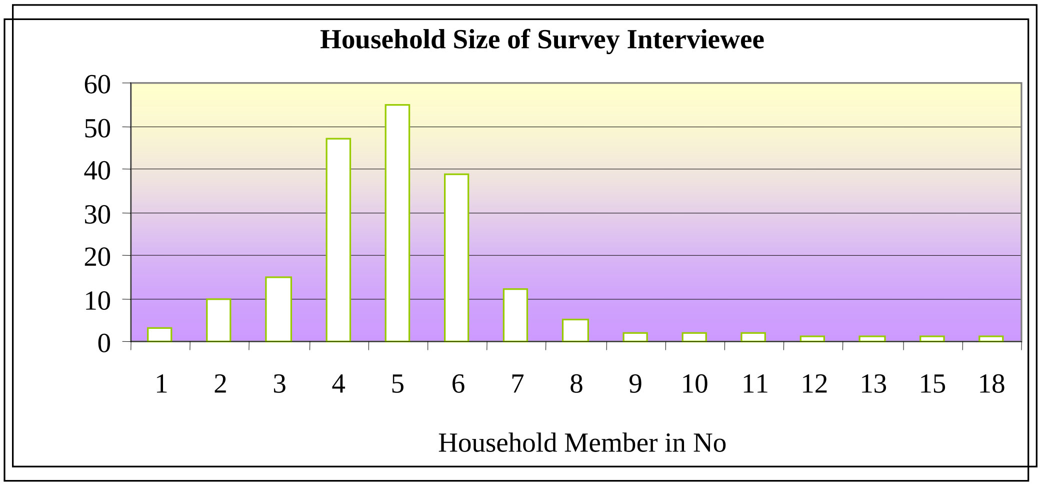

Figure 5.1 Household size of residential consumers (Source: Survey, 2007).

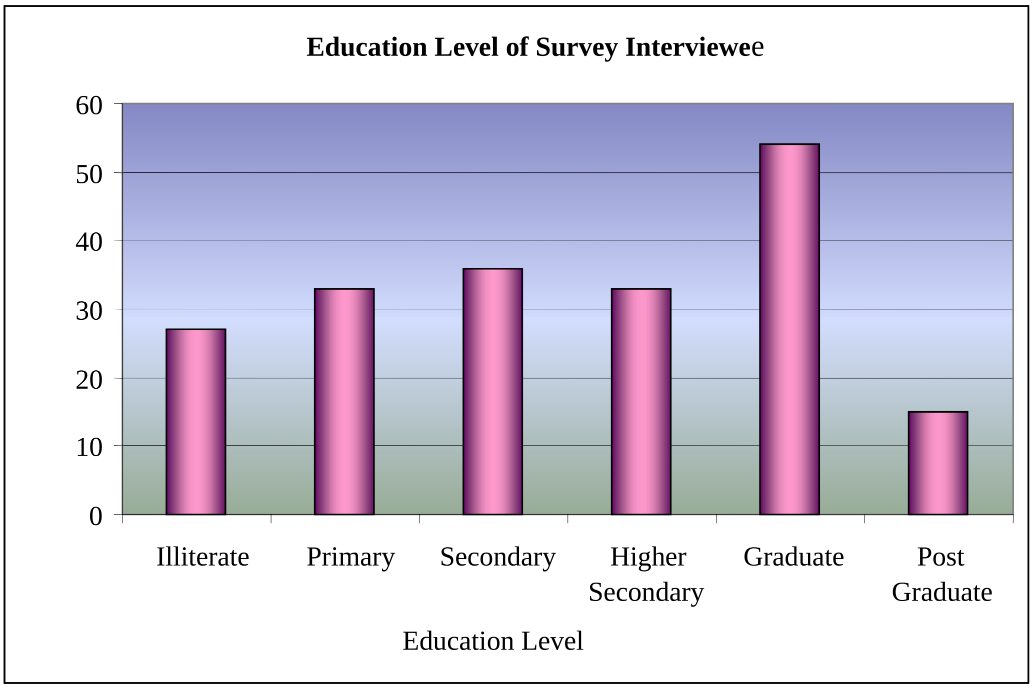

Figure: 5.2 Education levels of residential consumers (Source: Survey, 2007).

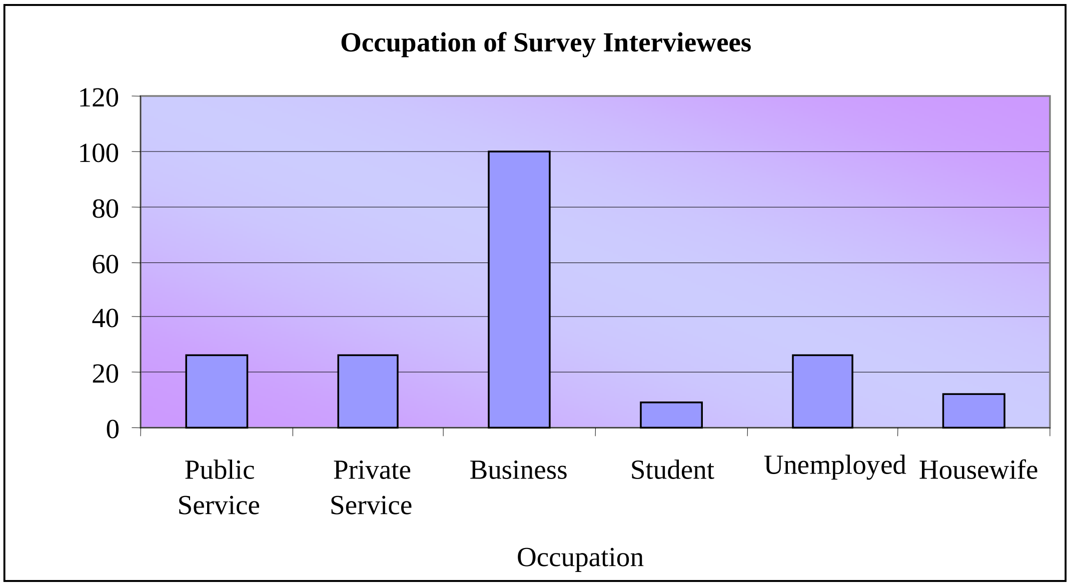

Figure 5.3 Occupation distribution of residential interviewees (Source: Survey, 2007).

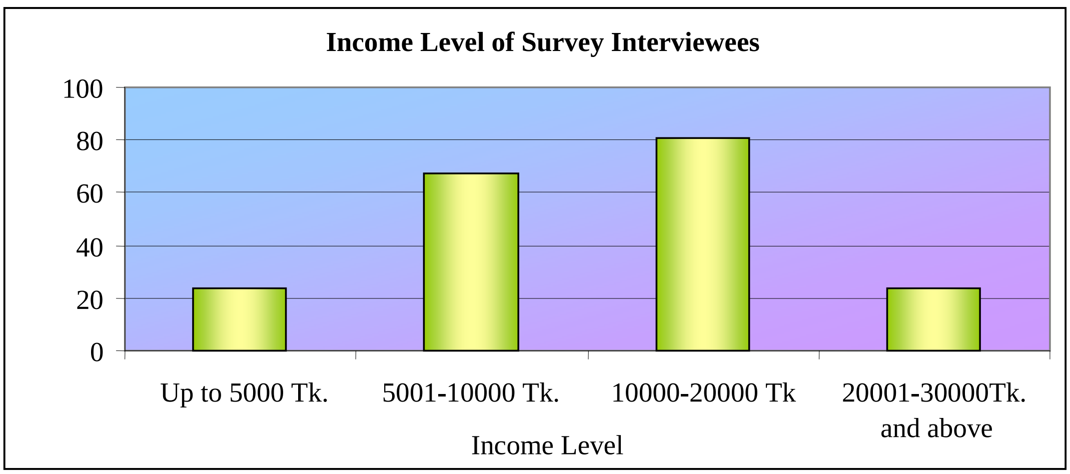

Figure 5.4 Income level of residential interviewees (Source: Survey, 2007).

Actual household member data and dummy variables are used to calculate descriptive statistics. There had been six categories of education level and four categories of income level identified for the residential consumers. If many data points are close to the mean, and then the standard deviation is small; if many data points are far from the mean, then the standard deviation is large. In this case, occupation levels are also identified in six categories. Frequencies of data for different dataset are presented by figures above. Descriptive statistics of dataset with minimum and maximum value are presented by table 5.2. Mean household member size is found to be 5 with a standard deviation of 2.16.

5.1.2 Satisfaction Survey Results

Consumers were inquired over their water supply satisfaction from different perspectives; quantity, quality, pressure, level of cooperation of water supplying authority and water tariff. Consumers were provided with satisfaction level or degree ranging from strongly dissatisfactory to strongly satisfactory. Consumers expressed their opinion regarding DWASA consumer satisfaction using fixed range of satisfaction level with five options. The results of satisfaction survey are presented using following figure.

This survey includes about 200 samples collected from two different zonal locations. It seems that consumers are more concerned with supplied water quality by DWASA from the results of AWI of different satisfaction parameters. Very few numbers of people are satisfied with DWASA supply from all perspectives. In addition to that, people had been enquired if they experienced any particular water quality problem; color, odor, bad taste. 86% of the interviewees complained of water quality and among them 27% complained of unclean water with bad smells. 90% of the respondents complained that do not get any prior notification about timing or duration of water unavailability.

Five different parameters have been set to gain more understanding about present condition of DWASA water supply service. Consumer responses were collected and categorized according to previously selected range. Satisfaction index for all the parameters are found in the middle range of fair, neutral or just enough. In Dhaka City, DWASA has monopoly on water supply. Thus, general people are not interested in giving any comments regarding tariff or quantity satisfaction. Spontaneous responses had been observed for quality and cooperation satisfaction questions which are reflecting the lowest results of AWI in the following table.

Table 5.2 Descriptive statistics of satisfaction parameters for residential consumers

Satisfaction Parameters	N	WAI	Satisfaction Level	Std. Deviation
Quantity satisfaction	196	0.59	D	0.24
Pressure satisfaction	199	0.56	D	0.20
Quality satisfaction	199	0.52	D	0.24
Level of cooperation	183	0.48	D	0.19
Tariff satisfaction	195	0.60	S	0.23

Note: S= Satisfied, D= Dissatisfied; Source: Survey, 2007

Chi-square test is performed to test relations between income and different satisfaction parameters. It has been found that water quantity and quality satisfaction are influenced by income level of consumers whereas tariff satisfaction is non responsive to income level. It can be said with 95% confidence that income of consumers have significant relation with quantity and quality satisfaction whereas income level and tariff satisfaction is not related with that. Consumer from different income levels assumes DWASA has scope of improvement in the case of supplied water quantity and quality. Their ideas about water tariff structure is unclear among all groups of people and thus presents a challenge to use water pricing as a tool for water demand management in Dhaka City. Pearson chi-square results are presented below in the following table.

Table 5.3 Pearson Chi-square Results of Relation; Satisfaction Index and Income

Parameters	Pearson Chi-Square		
	Value	df	Asymp. Sig. (2-sided)
Income and quantity satisfaction	22.57	12	0.03
Income and quality satisfaction	24.85	12	0.02
Income and tariff satisfaction	12.76	12	0.39

Note: Significance level= 0.05 Source: Survey, 2007

Income has positive relation with quantity satisfaction parameters. Table A.9 supports that satisfaction index is higher for consumers with higher income. According to the consumers, their opinion or satisfaction is of no importance to DWASA and thus they have no concern over these matters. They are just trying to survive with the amount of water they are getting with certain pressure and quality. People are not much concerned about their tariff satisfaction as they are bound to pay whatever DWASA charges them for water consumption.

Consumers were enquired to rank the reasons behind water shortage in their area from their own perspective. Electricity shortage or load shedding, seasonal unavailability, leakage and then increasing number of illegal connections are the top most identified reasons ranked respectively behind growing water shortage.

5.1.3 Willingness to Pay Survey Results

In this part of the survey, consumers were enquired about their monthly water bill based on meter or non-meter consumption. Consumers perception on present water tariff based on satisfaction range and their willingness to pay for better service of water supply in terms of quality and quantity were also investigated.

Three particular questions were asked to assess price elasticity of demand of residential consumers. Consumers were provided with three hypothetical situation with 10%, 25% and 50% possible rise in water bill and their responses in consumption pattern changes were recorded. Reduction options starting from none, a bit, moderately, a lot and significant were provided to the consumers and from their responses price elasticity of demand has been calculated. Point expansion method of demand estimation is used assuming constant elasticity demand.

5.1.3.1 Price Elasticity of Demand

Answers to the hypothetical questions for possible price incrementing scenarios are assessed with different values. Significant reduction is assumed to be 50% reduction in water consumption. Likewise, a lot, moderately, a bit and none are equivalent to 25%, 15%, 5% and 0% reduction respectively.

$$\text{Price elasticity of Demand, e} = \frac{\Delta Q / Q}{\Delta P / P}$$

Where; P= price, Q= quantity, ΔP= change in price, ΔQ= change in quantity

Price elasticity demand for tapped water supply is usually found in the range of $-1<e<0$ meaning that quantity demanded with change in 1% change in price is less than 1% (Griffin, 2006). Mean of % of change in quantity and % of change in price are calculated. Overall price elasticity of demand for residential consumers has been found -0.53 with standard deviation of 0.25. At the same time, minimum elasticity is -0.06 and highest is -1.35. For increase in water bill for 10%, 25% and 50%, mean % change in quantity are found as 8%, 14% and 30% respectively. Consumers with higher income profile are less interested to reduce their water use and mean price elasticity of demand for income group above 20,000 Tk per month is about 0.46. Price elasticity of demand for lower income group is considerably higher about 0.65. Face to face interview confirmed that they are using very limited amount of water as only 7% of this income group gets 8 hrs or above of water supply in a day. The other 93% gets about 2 hrs/day (43%), 3 hrs/day (29%) and 21% out of them are receiving 5-6 hrs of water supply in a day. This lower income group has access to other options like local public standpipes, hand pumps, and pump houses. The reason behind their high price elasticity of demand is that they will reduce tapped water supply of DWASA and will opt for other sources more if they have to pay more for piped water supply at their houses. Consequently, they will reduce their piped water consumption but will increase uses from other sources.

5.1.3.2 Water Demand or Marginal Benefit Function

Point expansion method can be used to obtain marginal benefit curve of residential consumers (Griffin, 2006). Price elasticity of demand has been obtained using contingent valuation method in section 5.1.3.1. With present price and quantity and price elasticity of demand, a point on demand function can be obtained (Aquarius, 2007)

However, at present the households in Dhaka City are paying 5.5 Tk per cubic meter of tap water. In total, DWASA is supplying 346320 thousand cubic meters water for residential consumers. That gives one point for residential water demand curve of Dhaka City (28.86 million cubic meters, 5.5). In this case, constant price elasticity of demand or linear form is used to obtain this function.

The basic exponential inverse demand equation is

$$p = a * \exp(-\frac{q}{b})$$

With known, p and q, the value of the constants are obtained as, $b = -eq$, and

$$a = \frac{p}{\exp(\frac{1}{e})}$$

Replacing q with 346320 and p with 5500 and e with -0.53 as constant elasticity monthly water demand function found is

$$p = 36290 * \exp(\frac{-q}{183550})$$

Here q indicates thousands of cubic meters and p indicates Tk per 1000 cubic meter. Reverse demand curve as q=f (p) is obtained to estimate marginal net benefit of the consumers or surplus obtained by consumers. $q = b * (\ln a - \ln p)$, using values from previous values of (a) and (b) the following reverse demand or marginal benefit equation is calculated.

$$q = 183550(\ln 36290 - \ln p) \quad \text{Equation 5.1}$$

Here, maximum willingness to pay for the residential consumers is 36290 Tk per 1000 cubic meter which is 6.6 times higher than what they are already paying for tapped water supply. Surprisingly, emergency water supply by DWASA costs about 40000 Tk per 1000 cubic meter which is closer to the range of their maximum willingness to pay found from the equation above.

5.1.3.3 Tariff Satisfaction and Willingness to Pay

Consumers were interviewed about their present water tariff and whether they are satisfied with what they are paying. Following previously mentioned satisfaction range, consumers were provided with five options. The following table 5.4 presents their response in frequency and percentage.

Table 5.4 Tariff Satisfaction of Residential Consumers

Water Tariff Satisfaction	Frequency	Percent
Strongly satisfactory	19	8.88
Satisfactory	44	20.56
Fair	72	33.64
Dissatisfactory	38	17.76
Strongly dissatisfactory	22	10.28
Total	195	91.12
Missing	19	8.88

Source: Survey, 2007

Over 65% (161 out of 214) of the interviewees are interested to pay more for better service from DWASA in terms of better quantity and quality of water. These people are willing to pay 10-25% more of present water tariff for better service (24 hrs tapped water supply with potable quality).

Willingness to pay highly depends on income level of the consumers. It is generally assumed that people with more money are willing to pay more for better service. The survey results show that consumers of different income levels are willing to pay 10% more whereas only 35% of higher income level (20000 Tk per month or above) people are willing to pay 25% more for better service from DWASA. As explained in section 5.1 that high income level people are not interested to reduce their water use but willing to pay more for more water with better service. Consumers with low level of income are not getting much water for their daily use and are interested to pay more for more hours of tapped water supply. WTP can be categorized for two different objectives. The high level income and low level consumers are willing to pay more fulfilling different requirements; quality and quantity respectively. About 15% of the low income consumers are willing to pay 25% more of present water bill which indicates their desperation for meeting daily water requirement. Consumers have different opinions about present water tariff satisfaction but one thing seems common that they are all willing to pay more for obtaining better service from DWASA.

5.2 Commercial Consumers

In total, 169 commercial consumers of six categories were surveyed. Survey sample category and frequency are provided with table 5.1. Consumers were enquired about their satisfaction level regarding water quality and quantity supplied by DWASA and their willingness to pay and water uses criteria.

Different categorized consumers are covered under the two survey areas. Workshop, hair salon, hospital/clinic, restaurants and community centers are investigated to find their nature of water use and attitude towards change of water use. Some of the samples are collected from public and some others are from private services. At zone III, a number of private universities along with shopping malls with departmental shores are found which are absent at zone II. These samples are covered under others criteria in table 5.1.

Commercial consumers like hotels and hospitals have expressed that water is a vital need for their daily survival. For some hospitals, tapped water supply from DWASA is not enough and they have installed their own DTW for continuous water supply. DWASA permits to dig private deep tube wells and at present there are 1179 no of DTWs of other agencies in Dhaka City. This system requires the private agency to pay an annual fee to DWASA which varies with depth and diameter of pipe of tube well. Again, there are several hospitals which have connection with DWASA and gets daily supply of emergency water supply by DWASA emergency water supply truck. Although, these trucks are supposed to supply water to consumers at times of emergency with minimal amount of money, they are supplying commercial consumers on a daily basis. One emergency supply truck can supply 5000 liter or 5 cubic meter water which costs 200 Tk; eight times higher than regular tapped water supply.

Consumers were asked several descriptive questions and their opinion and assessment were explored. According to 50% of the consumers, they had to take some structural measures; underground reservoir and roof top tank for ensuring continuous water flow. Consumers are using jet pump at water supply line to induce water in their reservoirs and later on using pumps to raise water to roof top tanks. In this case, electricity availability has great relation with water availability. Incase of load shedding, they suffer from water shortage. Table supporting this statement is provided at appendix. More than 50% of the commercial consumers have reported that they are using generators to ensure electricity which in turn ensures water availability.

Consumers from the locations reported that they have meter and pay their water bills regularly. These consumers are not aware of different structures of water tariff for different type of consumers. At places, consumers have residence and business at the same area or some times in the same building. Specially, at zone II, people have been observed to bring necessary amount of water from their houses to their shops. Again, a lot of business places are placed at rented houses and paying water bills according to domestic consumer water tariff. This same scenario has been observed at zone II and zone III. Mainly, new commercial places like shopping malls, hospitals, private university buildings are registering themselves as commercial water consumers and paying water bill accordingly.

5.2.1 General Information

Commercial consumers were chosen using business type as the main criteria. Additional information was collected about no of employees, no of customers, no of working hours/day and working days/week is also collected. Overall, survey sample background information is presented below with table 5.10.

Table 5.5 Background Information of Commercial Consumer Survey

Working Hours		**Working Day**		**No of employees/day**		**No of customers/day**	
Category	Percentage	Category	Percentage	Category	Percentage	Category	Percentage
≤ 8 hrs	25.77	4 days	2.41	≤ 20	84.62	≤ 100	78.40
8-12 hrs	62.58	5 days	2.41	≤ 40	6.51	≤200	13.58
12-16 hrs	6.75	6 days	66.27	≤ 60	4.73	≤ 300	2.47
16-24 hrs	4.91	7 days	27.71	≤100	2.37	≤ 400	0.62
				> 100	1.78	> 500	4.94

Source: Survey, 2007

From the table above, it can be said that, most of the commercial places are open for 8-12 hrs a day for 6 days a week. 85% of survey samples consist of employee no less than 20 and about 78% of all the business places have about 100 customers a day.

5.2.2 Satisfaction Survey Results

Consumers have been enquired whether they are getting enough water for their daily use or not. They were also asked about quality, pressure of receiving water and service of DWASA. Their responses were also recorded if they are satisfied with present water tariff or not.

Average weighted index or AWI have been used to quantify consumer responses. The range and method has been discussed earlier in methodology section. On the scale of 0-1, quantity satisfaction is found about 0.65 which means according to consumers they are getting just about their requirement. Quality satisfaction ranges from 0.45-0.55 and pressure satisfaction is about 0.55. In both cases, consumers' responses stayed below 0.6 or dissatisfied. Present water tariff satisfaction is mostly ranged above 0.6 which means they are mostly satisfied with it.

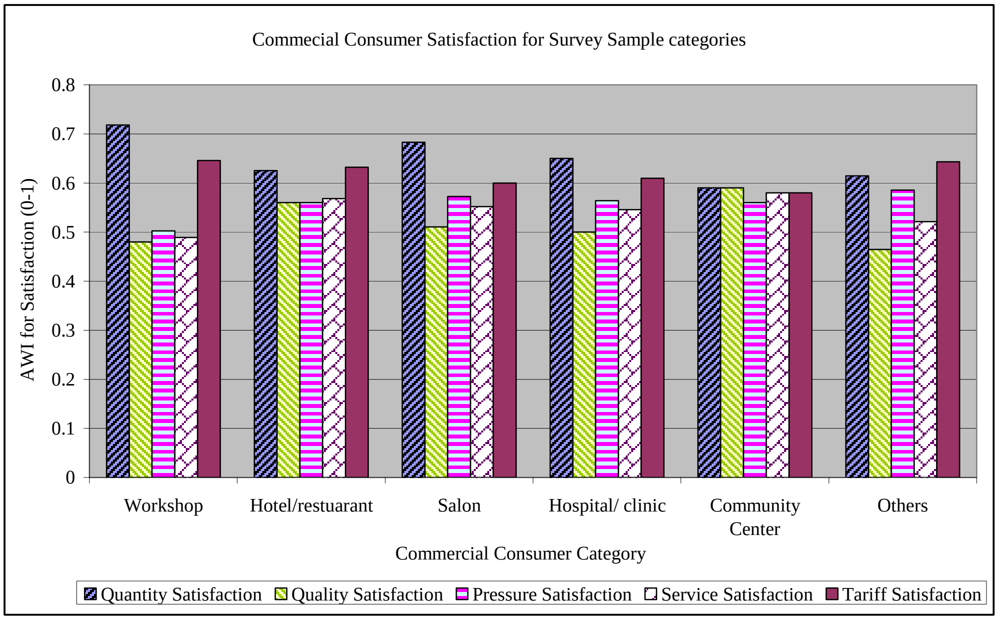

Figure 5.5 Commercial consumer satisfaction (Source: Survey, 2007).

Consumers were asked specifically about water shortage problem. 79% of the total interviewees responded that they have water shortage problem. This response seemed contradictory to the water quantity satisfaction response. Previously, consumers responded that they have "just enough" water for their daily use. More than 50% consumers answered that they face water shortage problem mainly during summer season which starts from February until May. This survey was conducted in the period of November to December which is considered as the winter period in Bangladesh. It seems that consumers get their requirement during winter and thus their response was above than 0.5. Their responses indicate at winter season, their satisfaction level is above average or 0.5.

5.2.3 Results of Willingness to Pay Survey

In this part of the survey, consumers were provided with three hypothetical situations with 10%, 25% and 50% possible rise in water bill and their responses in consumption pattern changes were recorded. Reduction options starting from none, a bit, moderately, a lot and significant were provided to the consumers and from their responses price elasticity of demand has been calculated. Point expansion method of demand estimation is used assuming constant elasticity demand.

5.2.3.1 Price Elasticity of Demand

Price elasticity demand for tapped water supply is usually found in the range of $-1<e<0$ meaning that quantity demanded with change in 1% change in price is less than 1% (Griffin, 2006). Mean of % of change in quantity and % of change in price are calculated. Overall price elasticity of demand has been found as -0.35 with standard deviation of 0.34. At the same time, lowest elasticity is found as -0.02 and highest as -1.76. For increase in water bill for 10%, 25% and 50%, mean % change in quantity are found as 5.25%, 9.33% and 15.61% respectively. Price elasticity of demand for different types of business is tabulated below. It seems that, hospitals, clinics and community centers are non-responsive to change in water tariff. Compared to domestic consumers, commercial consumers have a lower price elasticity of demand which indicates that they don't have much scope for changing water use.

Table 5.6 Price Elasticity of Demand for Business Types

Type of business	**PED**	**N**	**Std. Deviation**
Workshop	-0.52	45	0.28
Hotel/restaurant	-0.38	25	0.32
Salon	-0.47	29	0.40
Hospital/ clinic	-0.09	22	0.14
Community Center	-0.09	20	0.09
Others	-0.36	28	0.41

Note: PED= Price elasticity of demand Source: Survey, 2007

In support to the above finding, one other survey result can be described below. Consumers were provided with several options on hypothetical notes regarding emergency water unavailability or shortage. About 16% of the total consumers under survey responded that they will reduce water use incase of severe water shortage. 35% of the total consumers are willing to buy extra water (emergency truck) from DWASA and 14% are interested to reuse waste water to overcome water shortage situations.

Table 5.7 Alternative Options for Water Shortage Periods

Alternative Options	Frequency	Percent
Buy water from DWASA	59	35
Reduce water use	27	16
Reduce business hours	7	4
Reuse waste water	24	14
Use water saving technology	4	2
Others	33	20
Missing	15	9
Total	169	100

Source: Survey, 2007

5.2.3.2 Water Demand or Marginal Benefit Function

Point expansion method is used to obtain exponential inverse marginal benefit curve for commercial consumers. Price elasticity of demand has been obtained using contingent valuation method in section 5.2.3.1. With present price and quantity and price elasticity of demand, a point on demand function can be obtained (Aquarius, 2007)

However, at present commercial consumers of Dhaka City are paying 18.25 Tk per cubic meter of tap water. In total, DWASA is supplying 22 million cubic meter or 22000 thousand cubic meters water every month on average. In this case, constant price elasticity of demand or linear form is used to obtain this function.

Following equation explained before and using -0.353 as constant elasticity monthly water demand function for commercial consumers is

$$b = -0.353 * 22000 = 770$$

$$a = \frac{18250}{\exp\left(\frac{1}{-0.35}\right)} = 317764$$

$$p = 317764 * \exp\left(\frac{-q}{770}\right)$$

Here, q indicates thousands of cubic meters and p indicates Tk. per thousand cubic meters. Reverse demand curve as q=f (p) is obtained to estimate marginal net benefit of the consumers or surplus obtained by consumers. $q = b * (\ln a - \ln p)$, using values from previous values of (a) and (b) the following reverse demand or marginal benefit equation for commercial consumers is calculated.

q= 770(ln 317764-ln p) Equation 5.2

It is found from this equation that maximum willingness to pay for the commercial consumers per 1000 cubic meters in 317764 Tk. This figure is 17 times higher than what they are paying at this moment to DWASA. Commercial consumers are willing to pay 8.5 times more than the residential consumers for continuous water supply. This figure indicates huge possibility for DWASA to augment their revenue by providing better service to the commercial consumers.

5.3 Industrial Consumers

Different tanneries, bakeries, plastic and some oil mills have been investigated during this survey. Major industries are all around the perimeter of Dhaka City and out of range of DWASA service area. In the selected survey areas, about 40 samples have been collected from industrial consumers.

A number of leather industries are found in zone II survey area. These factories are to be located outside of Dhaka City in near future as chemicals from tanneries are hugely responsible for water and air pollution in the locating and neighboring areas. Most of the leather industries have 24 hr shifts going on for 7 days a week. There are several procedures for processing raw leather which requires constant water supply. Tapped water supply from DWASA is not enough for these industries and they have built their own supply system with deep tube wells. DWASA permits industries to install deep tube well after examining their need and local geographical condition. DWASA has authority to fix depth and diameter of pipe of deep tube well and collects annual fee according to these fixed criteria from the private company. In cases of tanneries according to production need, they extract about 10-20 Gallon or 40-80 liter water per hour. Incase of possible water tariff or annual deep tube well fee, they do not intent to reduce any water use. For processing leather, their water requirements are mandatory and without water they might just close down industry.

Bakery or small food producing industrial units have been found which have 8 or 16 hours of shift daily. These units are paying 500-10000 Tk per month for water bill. Mixing, washing are the main purpose of using water. Incase of emergency of water shortage, they have opined that they will buy water (emergency truck water) from DWASA or reduce production. Establishing own deep tube well has not been their primary concern. At the same time, several plastic industries (small scale) are found within city area. These industries all are located at different rented or privately owned households. At some places, the laborers or employees live and work at the same place which means water consumption is not only for commercial but also for domestic purposes also. Plastic and food processing industries require water for their daily activities, and are more inclined to reduce water use in response to possible tariff increase. These consumers are still attached to DWASA supply, but future expansion may cause them to shift outside of Dhaka City with their own water supply system.

CHAPTER VI

Water Demand Assessment and Management

In the previous chapters, present condition of water supply in Dhaka City has been investigated. Profiles of water consumers and performance of DWASA are evaluated using both primary and secondary data. This chapter analyzes the possible options to mitigate water demand based on findings of previous chapters. It has been found that residential water demand comprises the major share among total water demand in Dhaka City. Knowledge of variables affecting household water demand in Dhaka City are extremely important to control demand and it is important to identity the variables affecting urban water demand for Dhaka City and get prepared for meeting future demand in an organized manner. In this chapter, water demand models are formulated using cross-sectional and time-series data. There are various options that can be explored to manage water demand and improve financial condition of water supplying utility. In the previous chapter, price elasticity of demand for residential consumers is determined from primary data indicating that pricing of water affects water demand. In this chapter, role of water pricing is intensely investigated focusing on needs of Dhaka City dwellers and DWASA as well.

6.1 Household Water Demand Assessment using Cross-sectional data

Water consumption or demand function for residential consumers is analyzed using several socio-economic parameters collected from primary survey at Dhaka City on residential consumers. Multiple regression analysis in linear form is used to evaluate the influential parameters for assessing residential water consumption or demand (Y). Several independent variables are selected for this analysis. The independent variables chosen for primary analysis are income (X1), household size (X2), education (X3) and number of hours of piped water supply (X4). Ordinal data with different levels classified for education and income are used. And, scalar data for household size and average pipe water supply hrs per day are used. Monthly water consumption for different household is used as scalar data and relationship of this parameter with other independent variables are calculated.

Ordinal variables are coded to quantify them. Responses regarding income and education obtained from the field are quantified for this ordinary least squares regression subject to tests of goodness of fit and t-statistics significance. The coded values of ordinal dataset (education and income) are listed in table A.11.

Backward variable elimination method is used to enter all of the variables in the block in a single step and then removing them one at a time based on removal criteria of probability of F with entry at 0.05 and removal at 0.1. Five sets of models are analyzed with different data set every time using the same method of elimination. ANOVA test result are presented here for the chosen model tested for best fit in table 6.1.

The final model is chosen on the basis of highest R square value (0.22). Independent variables; education and pipe water supply hrs per day are rejected due to lowest t-value. This model can explain variation in water consumption by 22%. Model summary with R square values for the model chosen is listed in table 6.2.

Table 6.1 ANOVA Test Result for Linear Model Analysis

Model		Sum of Squares	df	Mean Square	F	Sig.
Linear	Regression	64615.9	2	32307.9	12.62	0.00
	Residual	227809	89	2559.65		
	Total	292424	91			

Note: Predictors: (Constant), Income, Household members

Table 6.2 Model Summary for Tested Linear Regression Models

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Linear	0.47	0.22	0.20	50.59

The final result for residential water consumption function is chosen and it is found that income is the most influencing factor in this case. For this analysis, micro data consisting of data from individual households have been collected and used. The two coefficients have statistical significance and expected sign. Monthly water consumption has positive relation with both income and household size. The estimated consumption equation is

$$Y = 2.66 + 24.48X1 + 3.175X2, \quad \text{Equation 6.1}$$

Linear demand model represents that income level increment of one level increase water consumption about 25 times. At the same time, it also implies that household member or household size has a positive relation with water consumption. Increase in household size for one member, it is expected that water demand will rise approximately three times than existing.

6.2 Household Water Demand Assessment using Time-series Data

In Dhaka City, around 35% of the total water supplied is lost due to administrative and technical losses. From average monthly bill data, it is clear that around 70% of supplied water is to residential consumers. Considering this loss, monthly water supply for residential water consumers data have been used for this study to obtain water demand assessment model. Data from January, 2000 to June, 2007 were used on total number of active residential connections, domestic water price per 1000 cubic meters, temperature and GNP per capita are used as influential variables affecting residential water demand in Dhaka City. The price variables for residential water prices are adjusted using inflation data published by BBS. Monthly data have been adjusted using formula explained in methodology chapter. GNP per capita is used as a proxy for household income data and adjusted for monthly basis using inter-year GNP growth rates. Number of connections is used as another proxy for population Data for dependent and independent variables have been collected for 90 months and trend lines (over time) of these variables have been featured in appendix A.

Linear and log-log forms of equations are used for estimating water demand of household consumers. Variables used for this model have been summarized with acronyms in table 6.3 using sample data of 90 months. Two sets of models are analyzed with same independent variables. Model summary in table 6.4 lists values of R^2 and standard error estimation. The results show that the linear model can explain the variation of dependent variable about 90% with standard error of 1832 whereas the log-log model can explain the variation by 88% with standard error of 0.08.

Table 6.3 Descriptive Statistics of Independent and Dependent Variables

Model	**Variables**	**Acronym**	**Mean**	**Std. Deviation**	**N**
Linear	Average Monthly Consumption in 1000 cubic meter	Y	26565.614	5756.47	90
	Residential water tariff per 1000 cubic meter	x1	5611.46	128.38	90
	Per capita income	x2	431.22	33.17	90
	Number of residential connections	x3	196030.	14593.78	90
	Mean monthly Temperature in ◦C	x4	29.685	4.137	90
Log-log	Average Monthly Consumption in 1000 cubic meter	Y	10.164	0.22	90
	Residential water tariff per 1000 cubic meter	x1	8.632	0.023	90
	Per capita income	x2	6.064	0.077	90
	Number of residential connections	x3	12.183	0.074	90
	Mean monthly Temperature in ◦C	x4	3.380	0.15	90

Table 6.4: Model Summary of Residential Water Demand Model

SL No	Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
						R Square Change	F Change	df1	df2	Sig. F Change
1	Linear	0.95	0.90	0.90	1831.59	0.00	1.40	1	85	0.239
2	Log-log	0.94	0.88	0.87	0.08	0.88	150.69	4	85	0.000

Standardized coefficients of the model variables are explained in table 6.5. In both cases, coefficients of the explanatory variables have the expected signs. For water pricing the sign is negative and positive for income, no of connections and temperature. Coefficient of temperature is found insignificant in assessing water demand. In the case of linear estimation, weather variable temperature is removed due to low t-statistics value.

Income and number of connections are the most influencing variables for estimating household water demand. Price elasticity of demand estimated from the log-log analysis is -0.144. This is inelastic as 10 percent increase in water price results in 1.4 percent reduction in monthly water consumption. Income elasticity of demand is s 0.59 which shows 10% increase in income (GNP per capita) will increase 59% water use. Growth of GNP per capita is observed from figure B.5. GNP per capita is increasing steadily and in another 12 months it may cause 5.9% increase in water use as indicated from the results of demand model with steady increment in progress.

Table 6.5 Coefficients and t-statistics of Household Water Demand Model Variables

Model		Un standardized Coefficients		Standardized Coefficients	t	Sig.
Linear		B	Std. Error	Beta		
	(Constant)	-29446.75	13559.64		-2.17	0.03
	x1	-2.68	1.98	-0.06	-1.35	0.18
	x2	79.33	21.57	0.46	3.68	0.00
	x3	0.18	0.05	0.45	3.77	0.00
	x4	56.54	47.72	0.04	1.18	0.24
Log-Log		B	Std. Error	Beta	t	Sig.
	(Constant)	-8.774	5.338		-1.644	0.104
	x1	-1.351	0.482	-0.144	-2.802	0.006
	x2	-0.276	0.103	0.59	-2.680	0.009
	x3	2.518	0.141	0.35	17.826	0.007
	x4	0.100	0.057	0.069	1.749	0.084

The final equations chosen for residential water demand are:

$$Y = -28038.03 - 0.06x1 + 0.47x2 + 0.45x3$$, Equation 6.2

$$LnY = -8.774 - 0.114Ln(x1) + 0.59Ln(x2) + 0.35Ln(x)3 + 0.07Ln(x4)$$, Equation 6.3

In both cases, pricing of water seems to affect water demand or consumption very less compared to the other variables considered in this analysis. Price elasticity of demand is found as -0.144 and income elasticity of demand is found +0.59. This indicates that 1% increase in water price will reduce water use only 0.114% and 1% increase in income will increase 0.59% increase in water use.

6.3 Financial Environment of DWASA

Based on the objectives of water pricing discussed in literature review, revenue sufficiency and economic efficiency are the major ones for choosing reformed water pricing structure for water consumers of Dhaka City.

In general, revenue sufficiency provides the idea of average cost pricing (Griffin, 2006). In terms of economic efficiency, this idea is completely outdated as there will be loss of efficiency. Economic efficiency promotes the idea of marginal cost pricing which can lessen the quantity demanded and support water conservation. In reality, it is needed to find out where DWASA stands at this time with water pricing. Although, average cost pricing is not a compelling option from various literature review, it is considered helpful for a public water utility with the goal of supplying water to the city dwellers without making any turnover from it.

Management information report published by DWASA for the month of June, 2007 produces financial data regarding revenue income, revenue expenditure for O & M and capital expenses. A minor share of revenue is used for capital expenditures which are not related with augmentation of water supply. This expenditure is mainly dealt with purchase of vehicles, computers, meters and other purchases related with procurement and development (DWASA, 2007). As marginal cost is supposed to reflect the cost of supply one unit of additional water supply, it can be safely assumed that marginal cost is not the main concept applied by DWASA. The major capital expenditures are mostly financed by Annual Development Plan (ADP) allocations usually consisting both Government findings and foreign borrowings in the form of multilateral and bilateral financing (ABD, 2006). Surface water treatment plant which is currently supplying about 18% (225 MLD) of the total production had been constructed with the financial aid of World Bank under the Fourth Dhaka Water Supply Project.

There had been several options considered in the report of Fourth Dhaka Water Supply Project published in 1998 funded by International Bank for Reconstruction and Development (IBRD) under the Dhaka water resources management program. The options considered were reduced service hours, reducing service pressure, quantity rationing, district flow control, public campaign to reduce water wastage and others. Water supply in Dhaka City is intermittent for a number of areas with extremely low service pressure. It was also identified that political actors were not willing to bring any change to tariff structure.

Finance and Accounting Division of DWASA prepares detailed water supply or selling cost for different supply sources. From the detailed calculation, it can be seen that this costing includes only operation and maintenance costs and system loss is not considered for calculating total production cost. According to DWASA, an average of 6.96 Tk and about 11 Tk is used for selling 1 cubic meter of water from the sources of deep tube well and surface water treatment plant. Due to the reasons mentioned above, capital cost of water supply in Dhaka City does not get reflected in water production cost. Water costing data is available for fiscal year of 2004-2005 and 2005-2006. The dataset of total cost for other fiscal years have been calculated using interpolation methods. Marginal cost and revenue are calculated for one additional unit of water supply using operational cost and revenue. Average cost and revenue are calculated from total supplied water and the total operational cost and revenue. Total revenue data and capital expenses from revenue are gathered from MIS Report of June, 2007 and listed in table 6.6.

Table 6.6 Financial Cost and Revenue of DWASA

Year	TQ in Mcm	TC in Million Tk.	TR in Million Tk	O & M Cost in Million Tk	AC	AR	MC	MR
1999-2000	386.22	2253.86	1397.21	2252.97	5.83	3.62		
2000-2001	414.146	2374.95	1524.46	2373.46	5.73	3.68	4.34	4.56
2001-2002	444.06	2574.53	1756.98	2571.03	5.79	3.96	6.67	7.77
2002-2003	493.542	2755.91	1961.33	2748.40	5.57	3.97	3.67	4.13
2003-2004	516.047	3036.12	2256.53	3019.60	5.85	4.37	12.45	13.12
2004-2005	527.312	2683.94	2146.76	2680.63	5.08	4.07	-31.26	-9.74
2005-2006	514.068	3241.79	2430.29	3083.27	6.00	4.73	-42.12	-21.41
2006-2007	516.918	3486.36	2898.00	3419.65	6.62	5.61	85.82	164.11

Note: TQ= Total Quantity, AC= Average Cost   Source: DWASA, 2007
TC= Total Cost , AR= Average Revenue
TR= Total Revenue, MC= Marginal Cost, MR= Marginal Revenue

Certain observations can be made from average cost and marginal cost expressions. Average costing is fairly stable over last 8 years whereas a certain change of pattern is observed in the case of marginal cost. The figure below shows the change in a visual manner.

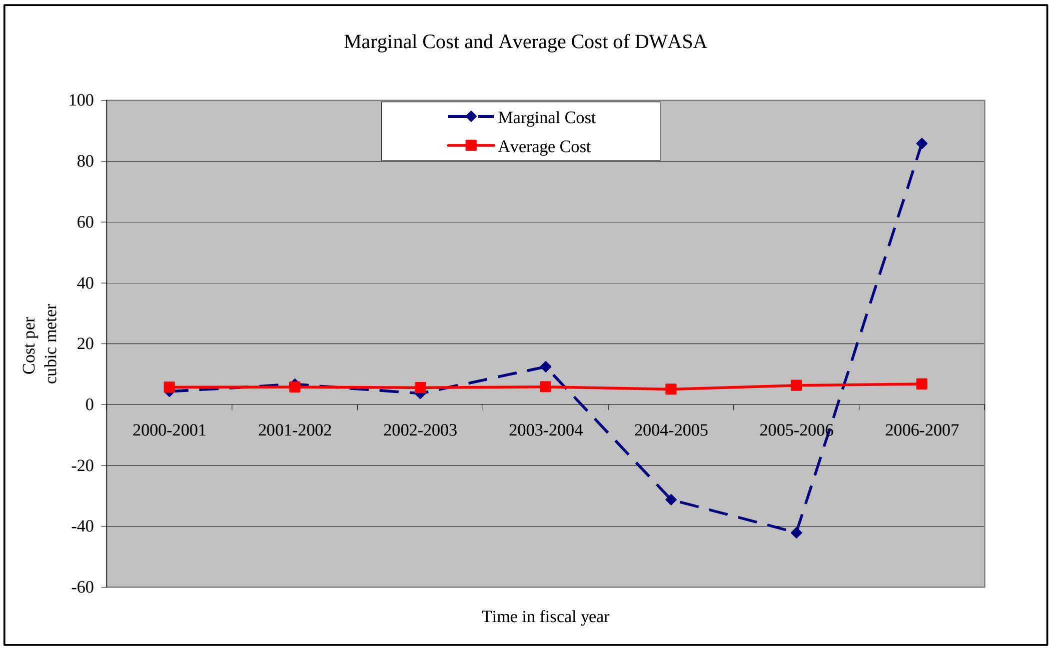

Figure 6.1 Marginal and Average cost of DWASA (Source: DWASA, 2007).

There is sudden change in marginal cost observed during 2005-2006 which is due to development of bottled water plant by DWASA. This cost incurs capital expenses from revenue. Over the years, the operation and maintenance costs have increased as administrative cost has increased considerably after application of upgraded staff salary scale. DWASA has the authority to increase water tariff based on inflation and power cost increment based on power adjustment clause. For the other cases, authorization of government is required to increase water tariff. The trend line of AC is steady and thus DWASA is following the process of average cost pricing. Marginal cost pricing will require changing the price hugely in an annual basis which contradicts authority of DWASA and public acceptance.

In this regard, it is attempted that DWASA can be well sufficient in covering its operation and maintenance cost from its revenue. WASA act supports non-profit water supply. Considering the condition, average cost and revenue of DWASA needs to be equalized including major water supply augmenting actions, operation and maintenance cost and capital cost covered by annual revenue. In the case of DWASA, figure 6.2 expresses average financial cost and revenue. This figure shows an existing difference throughout the whole period of analysis which finally producing the difference of 1.13 Tk per cubic meter. This graph represents the financial deficit of DWASA and presents the need of new pricing strategies to recover its annual expenditure (supply augmentation actions).

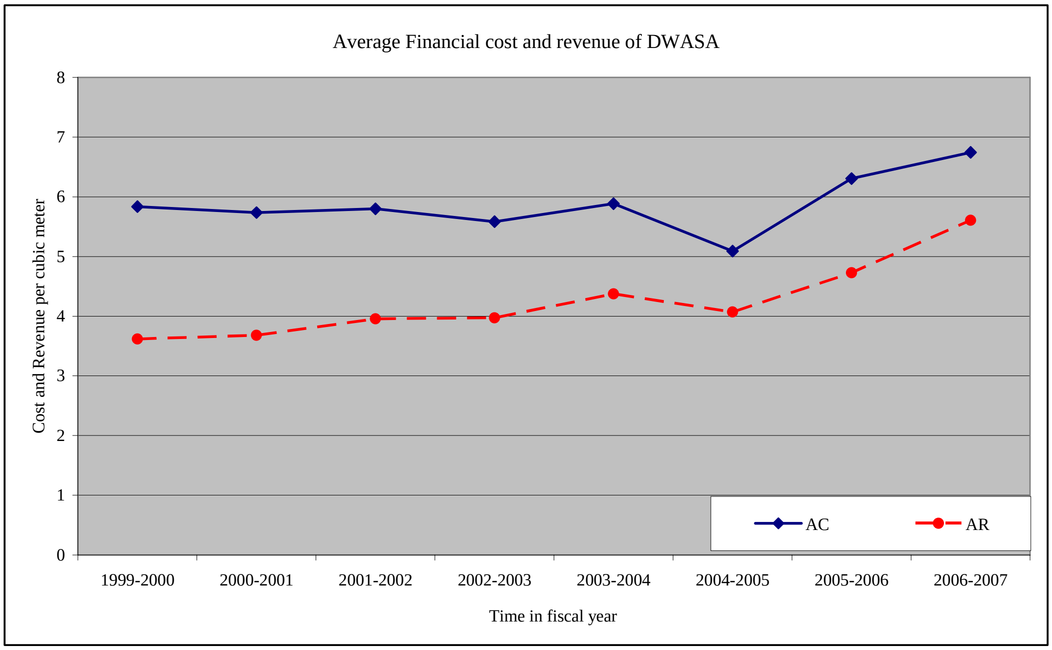

Figure 6.2 Average Cost and Revenue of DWASA (Source: DWASA, 2007).

The trend line of AC and AR follows similar pattern which shows rise from year 2004. Even then, DWASA seems to close down the difference between AC and AR in last eight year period of time.

6.4 Regression Model of Annual Revenue for DWASA

Annual revenue income of DWASA consists of several components. The major share is consisted of collected water billings. Water sales by vehicle, meter sale, connection fee, and DTW license / renewal fee are the other sources of revenue income of DWASA. To ensure pricing as a strategy for water demand management in Dhaka City, regression analysis is conducted for annual revenue of DWASA. Regression analysis with 8 years of data for residential water tariff, commercial water tariff, revenue collection efficiency and number of total connections are tested with observed annual revenue data. It has been clear from the previous demand model discussed in section 6.2 that the existing water tariff is not affecting water consumption to a great extent and it is also not providing enough revenue for DWASA which is clearly present from figure 6.1. It has been further clarified in chapter IV that a large amount is receivable every year. Thus, revenue collection efficiency is another variable considered for annual revenue collection. As DWASA is following “no profit no loss” policy while supply water to city dwellers, the focus of this analysis is to equalize average cost and average revenue.

Dataset from fiscal year of 1999-2007 are considered for this analysis. OLS analysis has been conducted using four independent variables; residential water tariff per 1000 cubic meters, commercial water tariff per 1000 cubic meters, revenue collection efficiency and number of total connections. Average inflation over eight years period of time has been used to get discounted water tariff and revenue. Impact of every independent variables are considered for obtaining annual average revenue which can predict financial condition of DWASA and lessen the difference between average cost and revenue. The following table provides the variables considered for this analysis and later on possible scenarios will be explored to lessen the gap between AC and AR by simulating different scenarios to improve AR of DWASA.

Table 6.7 Descriptive Statistics of Dependent and Independent Variables

Variables	**Acronyms**	**Mean**	**Standard Deviation**
Discounted residential Tariff per 1000 cubic meter	x1	5946.03	258.690
Discounted commercial Tariff per 1000 cubic meter	x2	19104.21	701.786
Revenue Collection Efficiency	x3	0.82	0.060
No of Connections	x4	213737.875	18997.955
Discounted total revenue in thousand taka	Y	2473402.352	239369.074

Table 6.8 Model Results for Annual Revenue Regression

Model	**F statistics**	**F-critical**	R^2
Linear	3.187	0.184	0.810
Log-Log	3.523	0.164	0.824

Linear and Log-log models have been used to estimate annual revenue relation with other variables. Assuming an Alpha value of 0.05, v1 = n–df-1 = 4 and v2 = df =3, the critical level of F is 0.184 and 0.184 and 0.164 for the two models. Since F = 3.18 and 3.52 which is higher than F critical values, it is unlikely that an F value occurred by chance. (With Alpha = 0.05, the hypothesis that there is no relationship between known_y's and known_x's is to be rejected when F exceeds the critical level.) In this regard, it can be safely assumed that the regression equation is useful in predicting the assessed value of annual revenue. Then again, the coefficient of determination achieved from the two model analysis explains that these models can explain the variation in annual revenue by more than 80% which is considered a good result for linear regression analysis. Using coefficients from both models, predicted annual revenue have been calculated. The differences in both cases for observed and predicted Y are calculated as % error. Table 6.12 and table 6.13 are used to test the forecasting ability of the models for the same data period used for analysis.

Table 6.9 Annual Revenue Forecast using Linear Model

Annual Revenue Forecast using Linear Model						
x1	**x2**	**x3**	**x4**	**Observed Y**	**Predicted Y**	**% error**
6169.011	20085.153	0.930	191087	2187076.6	2241030	-2.467
6079.041	18912.573	0.816	202894	2373500.9	2395148	-0.912
6042.152	19080.481	0.774	212543	2494868.3	2457988	1.478
5988.852	18864.883	0.807	217003	2702801.1	2524498	6.597
5921.181	18654.540	0.796	225489	2421212.6	2612470	-7.899
5575.500	18585.000	0.803	232907	2580966.9	2652636	-2.777
5500.000	18250.000	0.899	243477	2898000	2809277	3.062

Table 6.10 Annual Revenue Forecast using Log-Log Model

Annual Revenue Forecast using Log-Log Model						
x1	**x2**	**x3**	**x4**	**Observed Y**	**Predicted Y**	**% error**
8.727	9.908	-0.072	12.160	14.598	14.618	-0.133
8.713	9.848	-0.204	12.220	14.680	14.691	-0.076
8.707	9.856	-0.256	12.267	14.730	14.713	0.115
8.698	9.845	-0.214	12.288	14.810	14.739	0.475
8.686	9.834	-0.228	12.326	14.700	14.773	-0.498
8.626	9.830	-0.219	12.358	14.764	14.791	-0.187
8.613	9.812	-0.107	12.403	14.880	14.847	0.220

Based on highest R^2 and minimal % of error, Log-Log model is chosen for further analysis. The final model equation is as follows:

$$\text{Ln } Y = 11.54 + 0.157 * \text{Ln}(x1) - 0.74 * \text{Ln}(x2) + 0.1 * \text{Ln}(x3) + 0.743 * \text{Ln}(x4)$$

Equation 6.4

This model is satisfactory as it gives expected signs for all the explanatory variables other than commercial water tariff. As for the results, it is seen that increase in 1% commercial water tariff decreases 0.74% of annual revenue for DWASA. This result may be explained by marginal benefit curve for commercial consumers explained in section 5.2.3.2. From the equation, it has been seen that the maximum willingness to pay for the commercial consumers is Tk 317764 per 1000 cubic meters which is 17 times higher than their present water tariff and from survey questionnaire results of table 5.8 it has also been noted that about 35% of the total consumers are buying water from DWASA through emergency supply vehicle and about 20% are interested to buy water from local vendors who are selling extracted ground water from privately installed tube well. Therefore, increasing tariff for commercial consumers allure them to opt for other options than tapped water supply by DWASA. There are other possible options for increasing water revenue by increasing residential water tariff and revenue collection efficiency. Number of connections is providing with a high positive relation as well which indicates that with 1% increase in number of connection, DWASA will gain 0.74% more revenue.

6.5 Revenue Sufficiency Scenarios

Average cost and average revenue are used to clarify revenue sufficiency situation for DWASA. In this case, AC and AR per 1000 cubic meter are considered for last eight years data. From table 6.6, it is clearly seen that there is significant difference between AC and AR of DWASA. Cost recovery requires revenue to cover recurring costs while ensuring affordable service fee to all (Winpenny, 2003). Recovering cost and sufficiency in revenue may be possible by using the equation established in section 6.2.

Various scenarios with change in residential and commercial water tariff by +5%, -5%, +10%, -10%, +20% and -20% are analyzed for equalizing AC and AR. The other options to explore are to increase revenue collection efficiency and number of connections. Increasing number of connections will have impact on cost and thus this option will not be explored here. It is assumed here average cost incurred for water supply remains constant with the changes in residential water tariff, commercial water tariff and revenue collection efficiency.

Several changes are simulated in table 6.11 and table 6.12. The first scenario is used to simulate existing condition. Changes with ±5%, ±10% and ±15% in water tariff for residential and commercial tariffs are investigated individually and in combination. Different revenue collection efficiency (RCE) with +2% and +4% are simulated. The scenarios have been simulated by changing any one of the variables and other variables are kept constant.

Table 6.11 Simulated Scenarios for Average Revenue

Scenario Analysis	**Scenario 1**	**Scenario 2**		**Scenario 3**	
	Existing	+5%, Res	-5% Res	+5% Com	-5% Com
Adjusted AR in Tk/ m^3	5.55	5.60	5.51	5.36	5.77

Combinations of several changes in variables at a time are simulated in Table 6.16.

Table 6.12 Simulated Scenarios with Combination for AR

Simulated Scenarios	Change in Tariff		Change in RCE	Change in Tariff		Change in RCE	Change in Tariff		Change in RCE
	+5% Res	-5% Com	+2%	+15% Res	-5% Com	+4%	+20% Res	-10%, Com	+4%, RCE
AR in Tk/m^3	5.82			5.92			6.2		

Note: Res = Residential water tariff   Com = Commercial water tariff
AR = Average revenue   RCE = Revenue collection efficiency

Average revenue depends on various components and as from equation 6.4, several scenarios are tested. In these tables, (+) indicates increase and (-) indicates decreasing.

6.6 Total Surplus Estimation

Total surplus is used to assess efficiency of pricing as a water demand management tool for society as a whole. Total surplus is the added surplus from the consumer and the producer surplus that is caused by that product level. Total surplus quantifies the gains that come about from production and exchange. Total surplus is important as it explains exactly in what measure the situation has improved for the consumers and producers after they interact with each other. Maximized total surplus can achieve maximum efficiency. Total surplus is thus the primary measure used in welfare economics to evaluate the efficiency of a proposed policy.

Hence, marginal cost or supply curve is estimated using discounted cost value of DWASA for last 8 years with respect to supplied water quantity.

Supply and inverse supply curves for DWASA are estimated using simple regression analysis of which slope is nearly flat with positive vertical intercept.

$$P = 14017.83 - 0.0145Q$$
$$Q = 847547.7 - 52.14P$$

Equation 6.5

Here, Q is total annual production in 1000 cubic meters and P is cost per 1000 cubic meters. Consumer surplus and producer surplus have been calculated using marginal benefit and marginal cost curves. Inverse equations for marginal benefit curves of residential and commercial consumers are estimated in section 5.1.3.2 and section 5.2.3.2. The equations are following:

Residential water demand curve,

$$q = 183550(\ln 36290 - \ln p)$$

Commercial water demand curve,

$$q = 770(\ln 317764 - \ln p)$$

It is seen from the marginal benefit curve equations that maximum willingness to pay for 1000 cubic meter water for residential and commercial consumers are 36290 Tk and 317764 Tk. respectively. Integrated inverse demand curve or marginal benefit curve are integrated to obtain consumer willingness to pay with upper limit as maximum willingness to pay and lower limit as present and alternative price. At the same time, producer surplus is acquired from integrated marginal cost curve.

6.5.1 Residential Consumers

Different cases with different pricing policies are simulated for computing total surplus. Increase in price and decrease in price for 5%, 10%, 15% and 20% are explored by integration of supply and demand curve for specific limits.

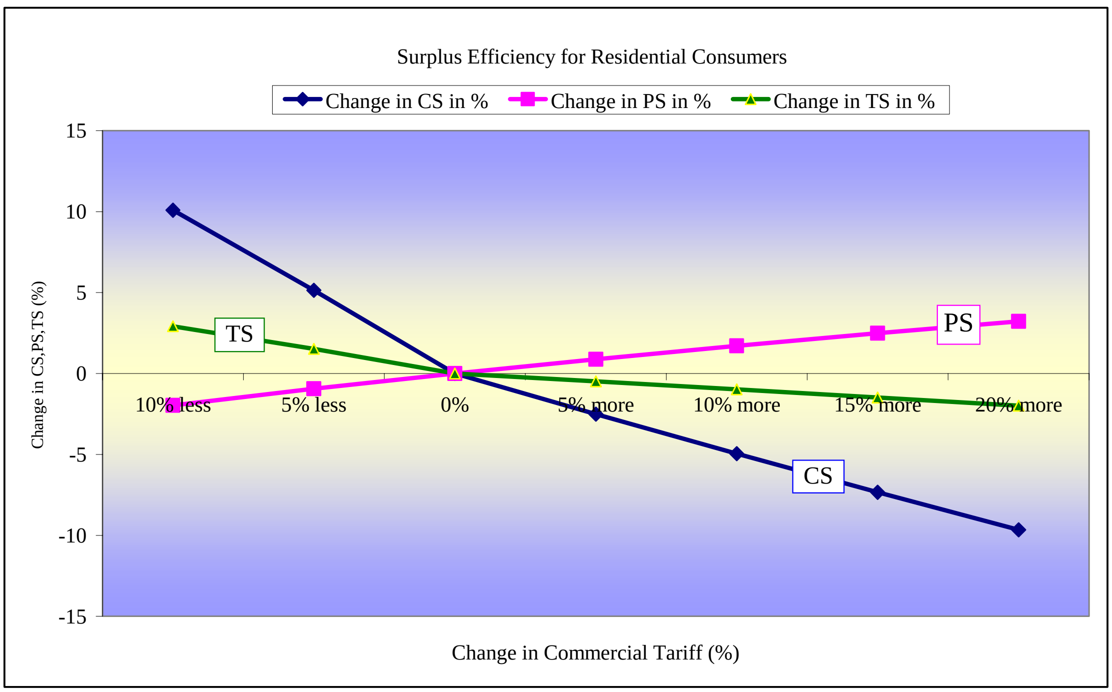

Figure 6.3 Change in Surplus for change in residential water tariff.

It is observed from figure 6.3 that increasing price results in decreasing total surplus. In this figure, 0% is used as a proxy for existing tariff condition. Maximum producer surplus (4% higher than present) is observed at change in tariff by 20% higher whereas it produces significant fall for consumer surplus (10% lower than present). This in turn produces about 2% change in total surplus. Here, present condition is considered as the stabilized condition which is not producing the maximum surplus and has potentiality for achieving maximum surplus with changes in tariff. Thus, it seems that although higher price is lessening total surplus (to a small extent), it may be of assistance in raising producer surplus for DWASA and thus increase average revenue.

6.5.2 Commercial Consumers

Different cases with different pricing policies are simulated for computing surplus efficiency. Increase in price and decrease in price for 5% and 10% are explored by integration of supply and demand curve for specific limits.

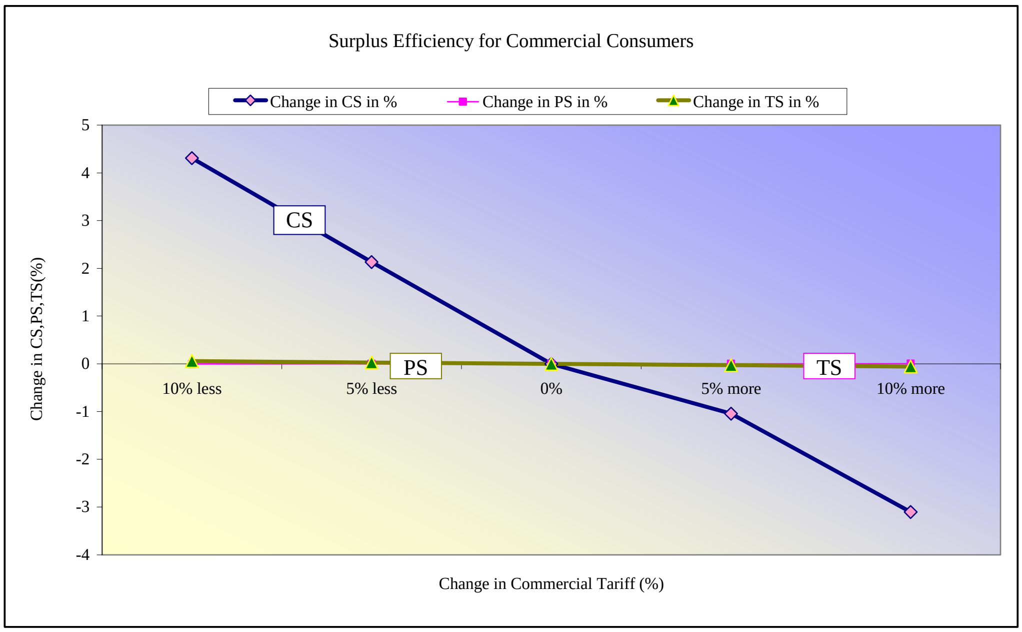

Figure 6.4 Change in Surplus for change in commercial water tariff.

The same trend of change in consumer surplus is observed from figure 6.4. However, the changes are not as much as for residential consumers. For 5% increase in water tariff, drop of 1% is observed. The same incidence brings about 3% change in CS is observed for residential consumers from figure 6.3. Producer surplus and total surplus change insignificantly in response to change in water tariff. Thus, it seems that any change in commercial water price may not enhance social welfare and will not be able to provide higher water revenue for DWASA.

CHAPTER VII

Summary, Conclusions & Recommendations

7.1 Summary

This study investigates water supply, demand features, and reconciliation strategies for Dhaka City, Bangladesh. The purpose of this study is to envisage demands of different water users, supply by water utility and related issues for whole society as well. Residential, commercial and industrial consumers are surveyed to evaluate their demand responsiveness to change in water price, their satisfaction regarding quality and quantity aspects and their willingness to pay for tapped water supply. Economic and statistical analytical tools are used to assess water supply and demand features.

DWASA is a public organization responsible for supplying water to Dhaka City dwellers. As a public service utility, it is hugely supported by subsidy and donor funding. Water supply is inadequate for growing water demand, yet varying from season to season. Operational and financial performance evaluation establishes that DWASA is not delivering appreciable service to the consumers and is unable to recover O & M cost and thus runs in financial deficit. Annual revenue collection of DWASA is assessed using time-series data, and confirms that residential water tariff, commercial water tariff and revenue collection efficiency have significant impact on total annual revenue. Analysis also suggests that increasing commercial tariff reduces annual revenue. Equalization of average cost and average revenue of DWASA requires a number of changes in combination and requires long-term planning.

It is established that income of residential consumers has significant effect on consumer satisfaction regarding water quantity and quality, suggesting that consumers with high income are more satisfied with current supply features. Consumer survey was conducted in the winter season from November to December. Water shortage is not a severe problem in winter and thus represents only a partial picture of demand responsiveness to water price. Consumer survey calculations reveal that short-term price elasticity of demand for residential and commercial consumers are -0.53 and -0.35 respectively. Commercial consumers are less inclined to change their water use in response to change in price. Using price elasticity of demand obtained from field survey, inverse exponential equation of demand for residential consumers is found as, $q = 183550(\ln 36290 - \ln p)$ for the residential consumers. Maximum willingness-to-pay of residential consumers is 36290 Tk. per 1000 cubic meter, which is 6.6 times higher than what they are already paying for. Inverse exponential equation of demand is, q= 770(ln 317764-ln p), for commercial consumers, where maximum willingness-to-pay of commercial consumers is 317764 Tk per 1000 cubic meters, which is 17 times higher than existing water tariff.

Income elasticity of demand and price elasticity of demand are calculated from household water demand models using time-series data in log-log format. Income of residential consumers is the most influencing factor onto household water demand. Long-term price elasticity of demand is calculated from secondary data on monthly basis for 85 months in total and found as -0.114 indicating consumers are willing to find new alternatives in future for water supply other than DWASA.

Effectiveness of pricing as water demand management tool is assessed for consumer, producer and social welfare. Increase in residential water price improves producer surplus for DWASA and generates some changes in total surplus. Change in commercial water tariff does not result in any change in social or producer welfare.

Consequently, reformation of water tariff for both residential and commercial consumers along with changes in administrative and managerial actions, like reducing system loss and increasing revenue collection efficiency can work out predicaments of consumers and water supplier at the same time, with water demand management as the core concept to be applied.

7.2 Conclusion

It is thus concluded that water pricing has potentiality in demand management and cost recovery to some extent. Several specific points are listed below:

- Population of Dhaka City is increasing which results in increasing water demand. Dhaka City water supply is hugely dependent on ground water which is depleting rapidly. Moreover, water supply authority of Dhaka City is enduring difficulties with operational service and financial deficit. Thus, it is concluded that water demand management is extremely important for Dhaka City and DWASA has to reform and restructure its operational and financial status to sustain which is possible with pricing as a water demand management and cost recovery tool.

- Income of residential consumers has significant effect on quantity and quality satisfaction whereas income level and tariff satisfaction is not related with that. Short term price elasticity of demand for residential and commercial consumers is -0.53 and -0.35 respectively. Maximum willingness to pay for the residential and commercial consumers is 6.6 times and 17 times higher than present water tariff increasing high willingness to pay. Income elasticity of demand is +0.59 which supports high WTP of consumers.

- Long term price elasticity of demand for household water uses is -0.114 indicating that consumers are not interested to reduce water use in long run.

- Household water demand model which explains variations in water use by 88% is; Ln Y=-8.774-0.114*Ln (Residential water tariff per 1000 cubic meter) +0.59*Ln (Per capita income) +0.35*Ln (No of residential connections) +0.07*Ln (Mean monthly temperature in ◦C).

- Role of water pricing in cost recovery and financial efficiency is important only if combined with revenue collection efficiency. Increase in tariff for residential consumers is effective for increasing annual revenue of DWASA but not effective for commercial consumers.

- Change in water tariff for residential consumers has positive relation with consumer surplus and produces negligible changes in total surplus or social efficiency. At the same time, change in commercial water tariff produces negligible changes in producer surplus and total surplus as well.

7.3.1 Recommendations for DWASA

Based on results from analysis, several recommendations for DWASA are listed below:

1. Revenue collection efficiency and system loss are important factors contributing to annual revenue of DWASA. Therefore, performance based management policy along with regular monitoring are needed to implement for improved financial condition of DWASA.

2. Water tariff structure needs to be updated annually considering inflation and increasing production and distribution cost. In addition, water tariff should be set based on consumer and producer welfare considering willingness to pay, affordability to pay of consumers and cost recovery of water utility. It is recommended to alter pricing structure for privately installed deep tube wells and formulate specific rules for extraction

3. Present configuration of water tariff is mostly unclear to consumers from all classes. Use of pricing as a water demand management requires dissemination of water tariff structure knowledge which is lacking at this time.

4. Consumer satisfaction index are needed to be set by DWASA to improve operational efficiency. Annual consumer survey should be conducted to communicate with the consumers and achieve understanding consumer satisfaction and affordability to pay.

5. Public Private Partnership (PPP) can be an alternative for improving service and recover costs based on the needs of consumers and DWASA. Findings of this study support the motives described in section 2.5 behind PPP for the concerned parties. Income of consumers is the main component affecting water demand and satisfaction index at the same time. WTP and ATP are considerably high which are required to motivate private investors. DWASA is in need of improving physical set up, coverage and management practices to serve consumers within constrained budget and other difficulties. Thus, it is recommended to investigate PPP as a possible option to meet demands of consumers and service utility (DWASA).

7.3.2 Recommendations for Future Research Works

1. Pricing alternatives with fixed and variable components and their effects on consumers, water utility and society should be investigated for different seasons and implementation periods (short run/long run).

2. Price elasticity of demand is needed to assess at different seasons for different water uses to reform tariff structure accordingly. Field surveys are required to assess the real price responsiveness of water demand at summer, monsoon and winter season.

3. Pricing structure for different water uses under Public-Private Partnership (PPP) is required to be investigated from economic and financial perspectives.

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APPENDIX –A (TABLES)

Table A.1 Price Elasticity of Demand for Residential and Commercial Consumers

Consumer Category	Change in Quantity Demanded			ΔQ in %	ΔP in %	Price Elasticity of Demand
	10% rise in price	25% rise in price	50% rise in price			
Residential	4.86	12.68	27.60	14.89	28.33	-0.53
Commercial	5.25	9.33	15.61	10.06	28.33	-0.36

Source: Survey, 2007

Table A.2 Relation of electricity and water availability for commercial consumers

Piped water supply in hrs/day		Average load shedding hours in any day					Total
		0-3 hrs	4-6 hrs	7-9 hrs	10-12 hrs	above 12 hrs	
0-3 hr	% within Average load shedding hours in any day	1.85	0.00	2.50	0.00	0.00	1.39
4-6 hr	% within Average load shedding hours in any day	0.00	13.16	17.50	9.09	100.00	9.72
7-9 hr	% within Average load shedding hours in any day	3.70	28.95	27.50	27.27	0.00	18.75
10-12 hr	% within Average load shedding hours in any day	7.41	5.26	5.00	27.27	0.00	7.64
above 12 hrs	% within Average load shedding hours in any day	87.04	52.63	47.50	36.36	0.00	62.50

Source: Survey, 2007

Table A.3 Relation of Income level and Willingness to Pay for better service of DWASA (residential consumers)

WTP/Income level	Up to 5000 Tk. in %	5001-10000 Tk. In %	10000-20000 Tk in %	20001-30000Tk. and above in %
10% more	78.95	91.23	77.46	65
25 % more	15.79	3.51	18.31	35
50% more	5.26	0.00	2.82	0

Source: Survey, 2007

Table A.4 Production capacity and actual production by DWASA over time

Year	Number of Deep tube well	GW Production Capacity, Mcm/day	SW Production Capacity, Mcm/day	Actual water production, Mcm /day
2000	326	1.14	0.08	0.612
2001	353	1.20	0.08	0.612
2002	394	1.29	0.22	1.397
2003	391	1.28	0.26	1.391
2004	402	1.31	0.28	1.413

Year	Number of Deep tube well	GW Production Capacity, Mcm/day	SW Production Capacity, Mcm/day	Actual water production, Mcm /day
2005	418	1.34	0.31	1.441
2006	441	1.42	0.30	1.524
2007	465	1.51	0.29	1.603

Source: DWASA, 2007

Table A.5 Daily water distribution report for 28th October, 2007

Description		Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	SWT P	Total
No of DTW	Active Pump	78	42	72	97	97	73	16	1	534
Daily Water Production in M cm/day	Intended	0.279	0.193	0.250	0.245	0.332	0.223	0.087	0.225	2.112
	Actual	0.245	0.174	0.243	241	0.312	0.215	0.061	0.225	1.951
Pump winded down in hrs	Mechanical Reason	4	5	2	3	23	4	16	0	78
	Electricity Shortage	217	62	55	13	0	66	50	0	575
No of Generators	Active	40	32	33	36	39	43	4	1	264
	Under Repair	2	0			1		2		7

Source: DWASA, 2007

Table A.6 Annual revenue regression data

Year	Residential Tariff per 1000 cubic meter	Commercial Tariff per 1000 cubic meter	Revenue Collection Efficiency	TR in thousand taka
1999-2000	4130	13390	0.735	1397210
2000-2001	4300	14000	0.930	1524463
2001-2002	4500	14000	0.816	1756980
2002-2003	4750	15000	0.774	1961325
2003-2004	5000	15750	0.807	2256527
2004-2005	5250	16540	0.796	2146762
2005-2006	5250	17500	0.803	2430289
2006-2007	5500	18250	0.899	2898000

Source: DWASA, 2007

Table A.7 Commercial consumer category with satisfaction index and PED

Type of business	Descriptive Statistics	Quantity Satisfaction	Tariff Satisfaction	Quality Satisfaction	Pressure Satisfaction	Service Satisfaction	Price Elasticity of Demand
Workshop	Mean	0.72	0.65	0.48	0.50	0.49	0.52
	N	44	44	45	45	45	45
	Std. Deviation	0.15	0.14	0.19	0.18	0.17	0.28
Hotel/restaurant	Mean	0.63	0.63	0.56	0.56	0.57	0.38
	N	24	25	25	25	25	25
	Std. Deviation	0.15	0.12	0.22	0.20	0.17	0.32
Salon	Mean	0.68	0.60	0.51	0.57	0.55	0.47
	N	29	29	29	29	29	29
	Std. Deviation	0.18	0.11	0.18	0.17	0.15	0.40
Hospital / clinic	Mean	0.65	0.61	0.50	0.56	0.55	0.09
	N	20	21	22	22	22	22
	Std. Deviation	0.13	0.15	0.13	0.17	0.19	0.14
Community Center	Mean	0.59	0.58	0.59	0.56	0.58	0.09
	N	20	20	20	20	20	20
	Std. Deviation	0.22	0.13	0.22	0.23	0.22	0.09
Others	Mean	0.61	0.64	0.46	0.59	0.52	0.36
	N	28	28	28	27	28	28
	Std. Deviation	0.14	0.15	0.18	0.17	0.17	0.41
Total	Mean	0.66	0.62	0.51	0.55	0.53	0.36
	N	165	167	169	168	169	169
	Std. deviation	0.16	0.13	0.19	0.19	0.18	0.34

Source: Survey, 2007

Table A.8 Cross-tabulation of income and satisfaction parameters (Residential consumers)

Income Level	Upto 5000 Tk.	5001-10000 Tk.	10000-20000 Tk	20001-30000Tk.	Total
Quantity Satisfaction					
Seriously not enough	17.39	9.09	3.70	0.00	6.70
Not Enough	**43.48**	**36.36**	16.05	4.55	24.74
Just Enough	21.74	15.15	20.99	18.18	18.56
Enough	13.04	36.36	**55.56**	**72.73**	46.39
More than enough	4.35	3.03	3.70	4.55	3.61
Quality Satisfaction					
Strongly Dissatisfied	12.50	16.42	14.81	22.73	15.82
Dissatisfied	**37.50**	**59.70**	**65.43**	**54.55**	59.18
Neutral	33.33	7.46	7.41	18.18	11.73
Satisfied	16.67	10.45	12.35	4.55	11.22
Strongly satisfied	0.00	5.97	0.00	0.00	2.04
Service Satisfaction					
Strongly Dissatisfied	9.52	17.46	14.67	15.00	15.47
Dissatisfied	**57.14**	**50.79**	**40.00**	**35.00**	45.30
Neutral	23.81	23.81	28.00	20.00	24.86
Satisfied	9.52	6.35	14.67	25.00	12.15
Strongly satisfied	0.00	1.59	0.00	0.00	0.55
Tariff Satisfaction					
Strongly dissatisfactory	0.00	1.61	2.50	4.55	2.11
Dissatisfactory	20.83	17.74	12.50	4.55	14.21
Fair	**41.67**	**59.68**	**56.25**	**68.18**	57.37
Satisfactory	37.50	17.74	26.25	22.73	24.21
Strongly satisfactory	0.00	3.23	2.50	0.00	2.11

Table A.9 Supply curve data of DWASA

Year	Annual Water Production in1000 cm	Discounted cost per 1000 cubic meters
1999-2000	386220.00	8659.48
2000-2001	414146.00	8227.14
2001-2002	444060.00	6753.82
2002-2003	493542.00	6943.78
2003-2004	516047.00	7007.25
2004-2005	527312.00	5827.37
2005-2006	514068.00	6760.18
2006-2007	516920.00	6744.49

Source: DWASA, 2007

Table A.10 Household water demand regression data

Year	Month	Domestic Water supplied in Thousand cubic meters	Domestic Connections	GNP per Capita	Inflation in %	Domestic water price per cubic meter	Discounted Domestic water price/1000 cubic m
2000	January	18541.39	174484	371.67	4.46	4.13	5745.67
	February	18866.97	175443	373.33	4.46	4.13	5724.40
	March	19532.79	176696	375.00	4.46	4.13	5703.203
	April	20111.62	177726	376.67	4.46	4.13	5682.084
	May	19501.86	178178	378.33	4.46	4.13	5661.044
	June	19656.74	178828	380.00	4.46	4.3	5872.240
2000	July	19058.13	179454	381.67	4.46	4.3	5850.496
	August	20481.39	182612	383.33	4.46	4.3	5828.832
	September	19904.65	183185	385.00	4.46	4.3	5807.248
	October	20126.74	183737	386.67	4.46	4.3	5785.745
	November	19980.46	184280	388.33	4.46	4.3	5764.321
	December	20047.44	184280	390.00	4.46	4.3	5742.976
2001	January	20524.65	184652	391.19	4.49	4.3	5732.694
	February	19408.37	185040	392.37	4.49	4.3	5711.324
	March	20002.09	185474	393.56	4.49	4.3	5690.034
	April	19693.02	185978	394.74	4.49	4.3	5668.823
	May	20878.37	186478	395.93	4.49	4.3	5647.691
	June	20102.55	186979	397.11	4.49	4.3	5626.638
2001	July	20798.83	175924	398.30	4.49	4.3	5605.66
	August	20464.41	176505	399.48	4.49	4.3	5584.76
	September	20956.74	176969	400.67	4.49	4.3	5563.949
	October	20501.39	177441	401.85	4.49	4.3	5543.208
	November	21580.46	177940	403.04	4.49	4.3	5522.545
	December	21431.86	178471	404.00	4.49	4.3	5501.958
2002	January	22246.04	178979	405.60	5	4.3	5634.371
	February	22774.65	179670	406.97	5	4.3	5610.992
	March	22347.50	180519	408.35	5	4.3	5587.710
	April	23010.23	181475	409.72	5	4.3	5564.525
	May	27755.58	182435	411.10	5	4.3	5541.435
	June	30457.67	183077	412.47	5	4.5	5775.114
2002	July	21097.33	183684	413.85	5	4.5	5751.150
	August	23004.88	184655	415.22	5	4.5	5727.287
	September	23209.55	185429	416.60	5	4.5	5703.522
	October	22654.22	185929	417.98	5	4.5	5679.856
	November	21253.55	186814	419.35	5	4.5	5656.288
	December	22275.78	187292	421.00	5	4.5	5632.818
2003	January	22684.63	187899	422.16	4.14	4.75	5701.218
	February	22306.31	188553	423.59	4.14	4.75	5681.616
	March	24114.73	189319	425.02	4.14	4.75	5662.082
	April	21725.68	190270	426.45	4.14	4.75	5642.615
	May	24048.63	190964	427.88	4.14	4.75	5623.215
	June	31049.26	191690	429.32	4.14	4.75	5603.882

Year	Month	Domestic Water supplied in 1000 cm	Domestic Connection	GNP per Capita	Inflation in %	Domestic tariff per cubic meter	Discounted Domestic tariff/1000 cubic m
2003	July	21893.05	192324	430.75	4.14	4.75	5584.61
	August	24118.94	193166	432.18	4.14	4.75	5565.41
	September	22400.21	193636	433.61	4.14	4.75	5546.27
	October	23526.52	194417	435.04	4.14	4.75	5527.21
	November	24751.15	195140	436.47	4.14	4.75	5508.20
	December	27538.31	195774	438.00	4.14	4.75	5489.26
2004	January	25232.2	196234	438.08	4.49	5	5827.33
	February	24212	196917	438.25	4.49	5	5805.61
	March	26562.8	197374	438.43	4.49	5	5783.97
	April	26624.6	198058	438.60	4.49	5	5762.41
	May	30000	199095	438.78	4.49	5	5740.93
	June	29089.6	200046	438.95	4.49	5	5719.59
2004	July	27193.8	200584	439.13	4.49	5	5698.20
	August	27656.6	200584	439.30	4.49	5	5676.96
	September	27781	201141	439.48	4.49	5	5655.80
	October	28815.2	201740	439.65	4.49	5	5634.72
	November	28951.6	202293	439.83	4.49	5	5613.71
	December	29880	202838	440.00	4.49	5	5592.79
2005	January	30542.4	203506	442.50	4.14	5	5525.17
	February	31939.4	204216	445.00	4.14	5	5506.18
	March	30727.2	204919	447.50	4.14	5	5487.25
	April	30898	205647	450.00	4.14	5	5468.38
	May	32274.8	206109	452.50	4.14	5	5449.58
	June	33814	206917	455.00	4.14	5	5430.84
2005	July	30904.57	207575	457.50	4.14	5.25	5682.78
	August	30524.38	208478	460.00	4.14	5.25	5663.24
	September	31063.04	209059	462.50	4.14	5.25	5643.77
	October	32237.90	209672	465.00	4.14	5.25	5624.37
	November	32603.42	210255	467.50	4.14	5.25	5605.03
	December	32598.66	210765	470.00	4.14	5.25	5585.76
2006	January	33027.61	211154	470.83	5.14	5.25	5645.67
	February	33213.90	211614	471.67	5.14	5.25	5621.59
	March	32871.42	212217	472.50	5.14	5.25	5597.61
	April	33166.47	212972	473.33	5.14	5.25	5573.74
	May	35045.33	213539	474.17	5.14	5.25	5549.96
	June	35449.52	214316	475.00	5.14	5.25	5526.29
2006	July	34894.09	215027	475.83	5.14	5.25	5502.72
	August	34055.04	216203	476.67	5.14	5.25	5479.25
	September	34377.52	217368	477.50	5.14	5.25	5455.88
	October	34115.04	218201	478.33	5.14	5.25	5432.62
	November	34500.57	218754	479.17	5.14	5.25	5409.44
	December	34410.47	219470	480.00	5.14	5.25	5386.31
2007	January	35257.52	220095	480.85	4.5	5.25	5349.17
	February	35392.76	221030	481.70	5.33	5.25	5343.89
	March	35785.52	222331	482.55	5.47	5.25	5322.12
	April	36095.61	223396	483.40	6.09	5.25	5303.42
	May	37032.95	224627	484.26	6.78	5.25	5279.66
	June	35689.09	226578	485.11	7.8	5.5	5500

Table A.11 Quantification of ordinal data for Household water demand model with cross sectional data

Variables	Responses	Coding
Education	Illiterate	1
	Primary	2
	Secondary	3
	Higher Secondary	4
	Bachelor	5
	Post-graduate and above	6
Income	Upto 5000 Tk	1
	5-10000 Tk	2
	10-20000 Tk	3
	20-30000 Tk and above	4

Table A.12 Excluded variables for linear model analysis (1-5)

Model	Excluded variables	Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
2	X3	0.01	0.10	0.92	0.01	0.87
3	X3	0.00	-0.04	0.97	0.00	0.88
	X2	0.13	1.39	0.17	0.15	0.99
4	X3	0.02	0.15	0.88	0.02	0.89
	X2	0.13	1.36	0.18	0.14	0.99
	X4	0.14	1.38	0.17	0.14	0.89
5	X3	0.03	0.29	0.77	0.03	0.88
	X4	0.14	1.41	0.16	0.15	0.89

APPENDIX- B (GRAPHS)

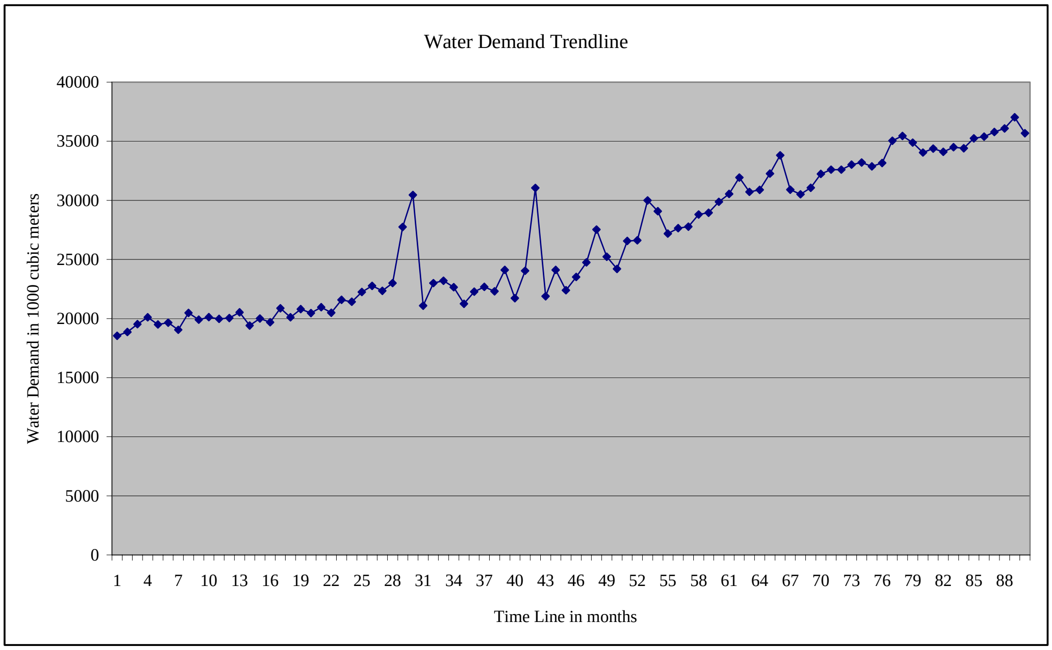

Figure B.1 Demand trend line (months under study period).

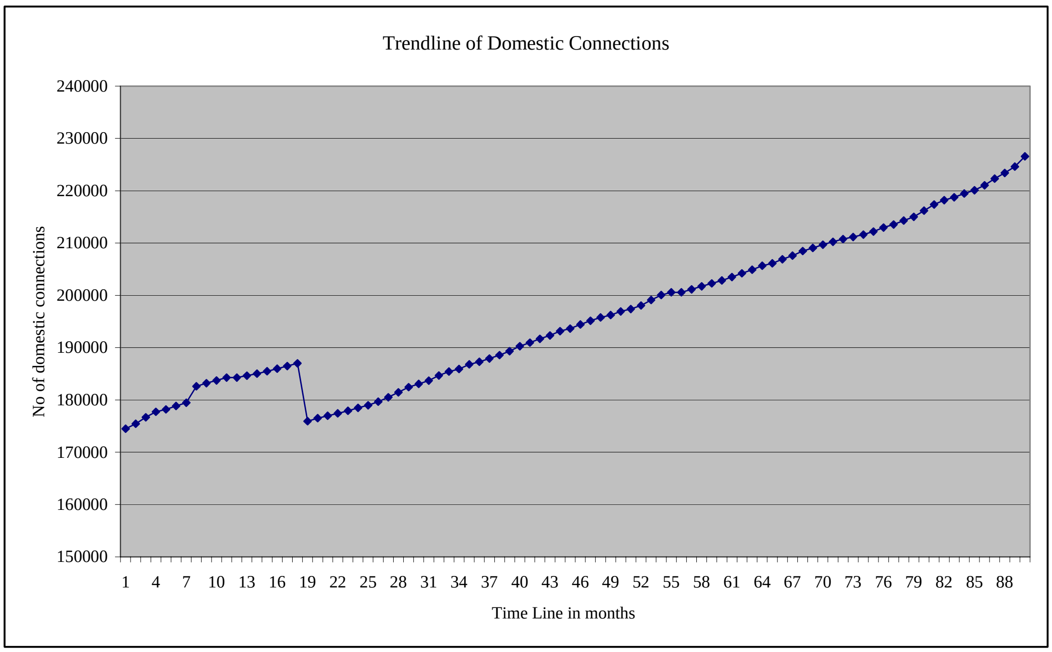

Figure B.2 Domestic connection trend line (months under study period).

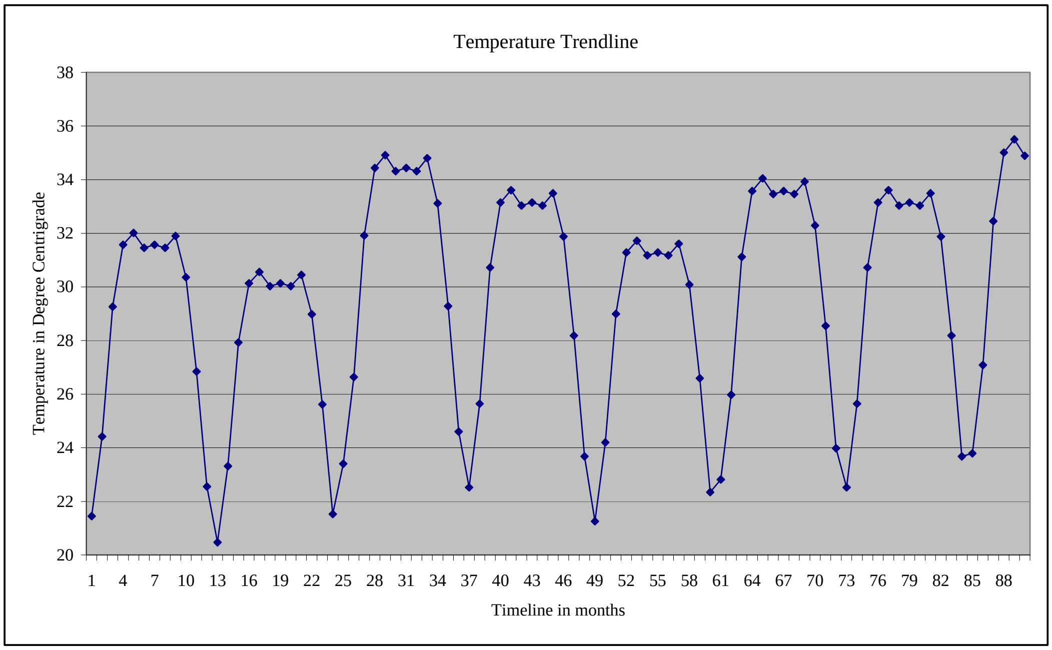

Figure B.3 Temperature trend line (months under study period).

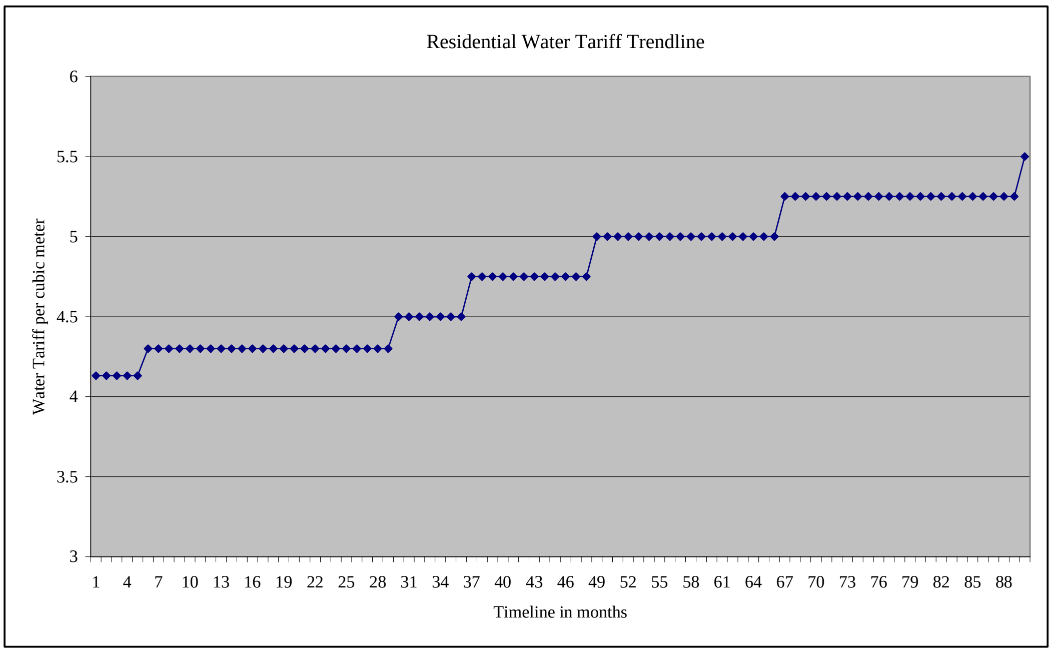

Figure B.4 Residential water tariff trend line (months under study period).

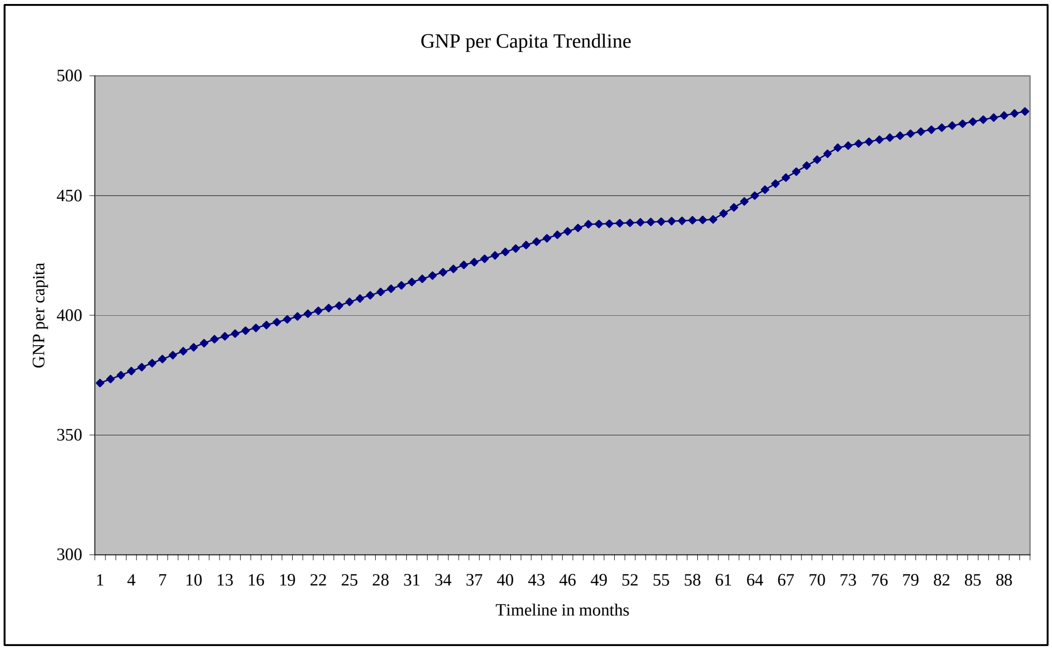

Figure B.5 GNP per capita trend line (months under study period).

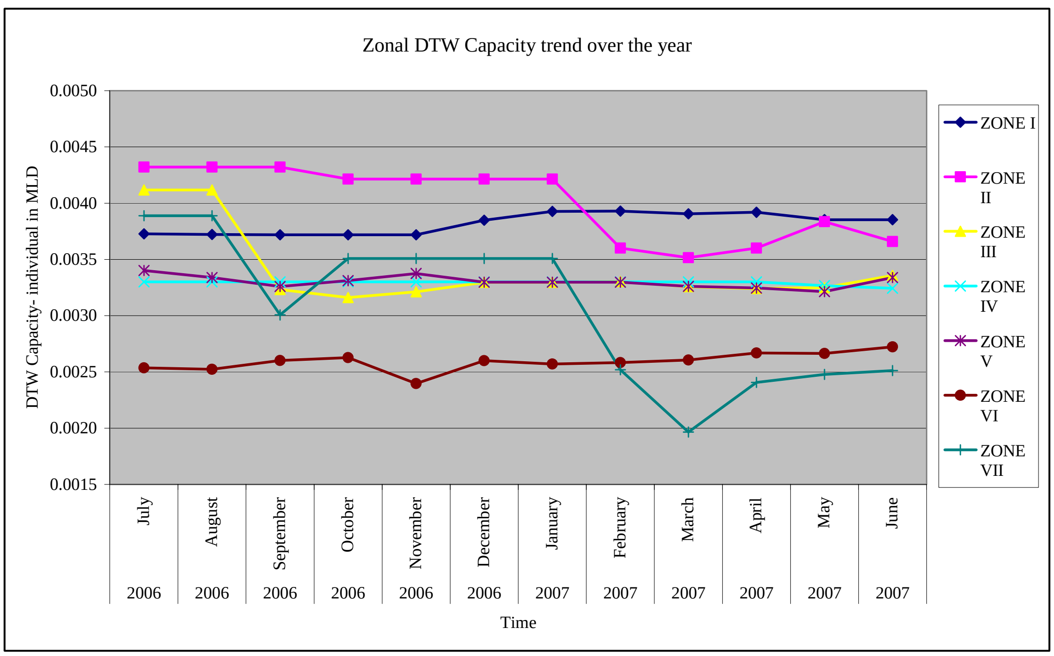

Figure B.6 Annual ground water production capacity trend for every zone.

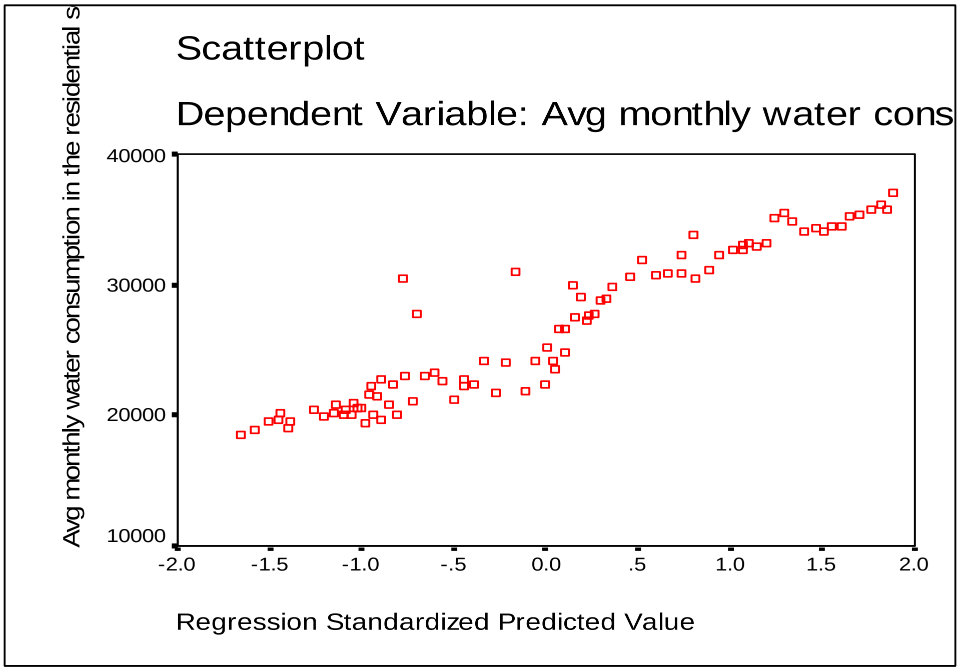

Figure B.7 Scatter plot of linear regression of average monthly water consumption.

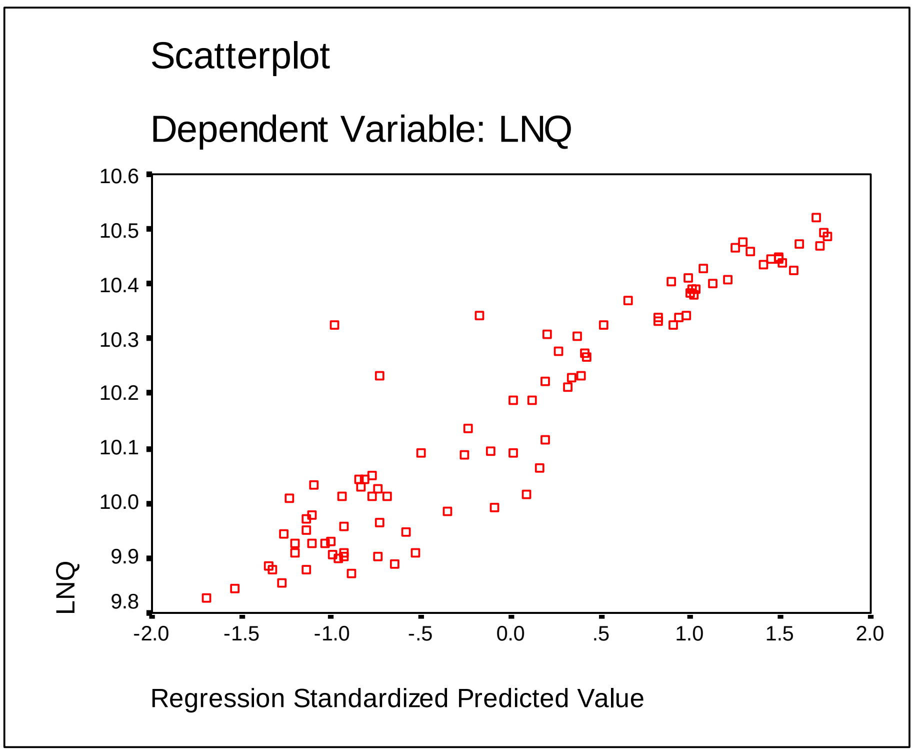

Figure B.8 Scatter plot of log-log regression of average monthly water consumption.

APPENDIX- C (Questionnaire)

Résidentiel Questionnaire Survey

Questionnaire Number…………..
Date of Interview………………..

Questionnaire for water users in Dhaka City

This questionnaire is solely made for a research purpose to understand the user perception on satisfaction, water tariff, and willingness to pay. The overall objective of this survey is to gather feedbacks on water demand, supply and alternative allocation arrangements during water shortage periods.

by
Sk. Naureen Laila

General Information:

Name: ……………………………………………………………………………..

Age: ………………….. Gender: ☐ M ☐ F

Address: ………………………………………………………………………………

Education: ……………………………………………………………………………..

Occupation: ……………………………………………………………………………

Income (monthly):

☐ 2000- 5,000 ☐ 5,000-10,000 ☐ 10,000-20,000 ☐ 20,000- 30,000 ☐ > 30,000

How many members in house (total)? ……………M ☐ F ☐ (number)

How many active water taps/connections in the house/apartment? ________

Do you take water from nearest street hydrant? Hand tubewell? Pump house?

Type of residence (Colony/Apartment complex/ Individual Housing/slum area)

☐ Kaccha ☐ Semi pucca ☐ One- storied ☐ Five storied ☐ Multi storied ☐ Hi rise

Roof tank/underground tank No ______ Capacity of tank ______ liter/gallon

Number of hours of piped water supply in a day _________hrs/ day
Number of hours of pump operation to fill tank _________hrs/ day

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Asian Institute of Technology (AIT), Thailand
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A. Water supply satisfaction survey

A.1 Do you possess meter in the house?

☐ Yes ☐ No

Is it in functioning mode?

☐ Yes ☐ No

A.2 Water supply

☐ Continuous ☐ Intermittent

If intermittent, how many hours of water supply do you get in one day? ____ hrs/ day

A.3 What are the times of any day you receive piped water supply? (Provide √ marks)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

A.4 Do you have water shortage problem throughout the whole year or in certain months? Whole year______(name months/season) (Provide √ marks)

Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec

A.5 Do you have enough water for daily use?

☐ Seriously not enough ☐ Not Enough ☐ Just Enough
☐ Enough ☐ More than enough

A.6 Are you satisfied with the supplied water pressure?

☐ Strongly satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐ Strongly Dissatisfied

A.7 Are you satisfied with the supplied water quality?

☐ Strongly satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐ Strongly Dissatisfied

A.8 Did you experience any water related diseases in last six months?(within family)

☐ Diarrhea ☐ Worms in intestine ☐ Typhoid ☐ Skin related ☐ Others_________

A.9 Have you experienced any water quality problem? (Provide √ marks)

☐ Color ☐ Odor ☐ Taste ☐ Difficulty in washing clothes ☐ Others__________

A.10 Are you satisfied with the level of operation or service the department provide during leakage, blockage and in case of no supply?
☐ Strongly satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐ Strongly Dissatisfied

A.11 Do you get any prior notification about timing or duration of water unavailability?

☐ No notice at all ☐ Less than 24 hrs of notice ☐ 2-3 hrs notice
☐ 1 Day notice ☐ 2-3 day notice

A.12 What are the reasons for water shortage in your area? (In your opinion)

Reasons	Tick	Rank	Comment
1. Seasonal unavailability (summer, winter)			
2. Leakage			
3. Increase in number of illegal connections			
4. DWASA failure____________________			
5. Discrimination between VIP and other areas			
6. Electricity failure; load shedding			
7. Lack of monetary support for DWASA			
8. Water pollution in and around Dhaka City			
9. Lack of policy support and implementation by the Government			
10. Others (specify)……………………….. …………………………………………….			

A.13 How do you cope with the situation when you don't have any water?

Do you need to buy water from WASA (not piped water)?

☐ Yes ☐ No

Do you need to buy water from other sources than DWASA?

☐ Yes ☐ No, if yes then name the source_________________________________

B. Willingness to pay survey

B.1 How much water you use for your uses on a daily basis? (Approximately)

…………………………………………liter/ bucket

B.2 Do you pay your WASA bills regularly? Is your bill based on meter reading?
☐ Yes ☐ No ☐ Yes ☐ No

B.3 How much money do you pay for your monthly water bill? (in TK)

☐ 0-100 TK. ☐ 100-200 TK ☐ 200-300 TK ☐ More than 300 TK

Do you pay sewerage bill also? If yes, then at what rate? ______________________

B.4 In your opinion, what are the purposes you pay the water bill for?

☐ Capital and other infrastructural works ☐ Maintenance ☐ Operational work
☐ Staff payment

B.5 How do you consider your present water tariff?

☐ Strongly satisfactory ☐ Satisfactory ☐ Fair
☐ Dissatisfactory ☐ Strongly Dissatisfactory

B.6 If your water bill increases 10% of what you are paying right now, what will you do? (Significantly = 80%, a lot=60%, moderately= 40%, a bit= 20%, none= 0%)

☐ Reduce significantly ☐ Reduce a lot ☐ Reduce moderately ☐ Reduce only a bit
☐ Reduce none

B.7 If your water bill increases 25% of what you are paying right now, what will you do? (Significantly = 75%, a lot=50%, moderately= 25%, a bit= 10%, none= 0%)

☐ Reduce significantly ☐ Reduce a lot ☐ Reduce moderately ☐ Reduce only a bit
☐ Reduce none

B.8 If your water bill increases 50% of what you are paying right now, what will you do? (Significantly = 75%, a lot=50%, moderately= 25%, a bit= 10%, none= 0%)

☐ Reduce significantly ☐ Reduce a lot ☐ Reduce moderately ☐ Reduce only a bit
☐ Reduce none

B.9 Will you consider paying more for continuous (24 hrs a day) piped water supply?

a) 10% more b) 25 % more
c) 50% more d) 100% more

B.10 Will you reduce your water use if you are charged 10% more of what you are paying right now? If, yes, then out of which purposes?

a) drinking
b) cooking
c) bathing
d) car-washing
e) gardening
f) personal hygiene
g) laundry
h) others ____________

B.11 Will you reduce your water use if you are charged 25% more of what you are paying right now? If, yes, then for which purposes?

a) drinking
b) cooking
c) bathing
d) car-washing
e) gardening
f) cleaning
g) laundry
h) others ___________

B.12 Will you reduce your water use if you are charged 50% more of what you are paying right now? If, yes, then for which purposes?

a) drinking
b) cooking
c) bathing
d) car-washing
e) gardening
f) cleaning
g) laundry
h) others ____________

B.13 Will you be satisfied with 70% of present water supply for the present price rate?

☐Strongly satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐Strongly Dissatisfied

B.14 Will you be satisfied with 50% of present water supply for the present price rate?

☐Strongly satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐Strongly Dissatisfied

Other comments:

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………….

---------------------------Thanks for your kind cooperation-----------------------

Commercial consumer Questionnaire Survey

Questionnaire Number…………..
Date of Interview………………..

Questionnaire for water users in Dhaka City

This questionnaire is solely made for a research purpose to understand the users' perception on satisfaction, water tariff, and willingness to pay. The overall objective of this survey is to gather feedbacks on water demand, supply and possible allocation scenarios during water shortage periods.

by

Sk. Naureen Laila

General Information:

Name: ………………………………………………………………………………..

Age: ………………….. Gender: [M] [F] Working day ____Working hour____

Location: ………………………………………………………………………………

Education: ……………………………………Designation: ………………………...

Name of Business: ____

Type of Business:____

No of employees working on a daily basis ____No of customers in one day ________

No of floors ____ No of toilet ____ No of generator ____Generator Capacity_______

How many active water taps/connections in the place?_________________

How many shifts of work go on daily? __________Duration of shift______________

Roof tank/underground tank No ______ Capacity of tank ______ liter/gallon

Number of hours of piped water supply in a day _________hrs/ day
Number of hours of pump operation to fill tank _________hrs/ day
Average load shedding hours in any day ______hrs/day

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School of Engineering and Technology
Asian Institute of Technology (AIT), Thailand
November 2007

C. Water supply satisfaction survey

A.1 Do you have meter for water?

☐ Yes ☐ No

Is it in functioning mode? Does DWASA check it regularly?

☐ Yes ☐ No

A.2 Water supply

☐ Continuous ☐ Intermittent

If intermittent, how many hrs of water supply do you get in one day? _______ hrs/ day

A.3 What are the times of any day you receive piped water supply? hr

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

A.4 Do you have water shortage problem?

☐ Yes ☐ No

If yes, when do you face this problem?

Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec

A.5 Do you have enough water for daily use?

☐ Seriously not enough ☐ Not Enough ☐ Just Enough
☐ Enough ☐ More than Enough

A.6 Are you satisfied with the supplied water pressure?

☐ Strongly satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐ Strongly Dissatisfied

A.7 Are you satisfied with the supplied water quality?

☐ Strongly satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐ Strongly Dissatisfied

A.8 Are you satisfied with the level of operation or service DWASA provides during leakage, blockage and in case of no supply?

☐ Strongly satisfied ☐ Satisfied ☐ Neutral ☐ Dissatisfied ☐ Strongly Dissatisfied

A.9 Do you get any prior notification about timing or duration of water unavailability?

☐ No notice at all ☐ Less than 24 hrs of notice ☐ 2-3 hrs notice
☐ 1 Day notice ☐ 2-3 day notice

A.10 What do you think are the reasons for water shortage or unavailability in your opinion?

Reasons	Tick	Rank	Comment
Seasonal unavailability (summer, winter)			
Leakage			
Increase in number of illegal connections			
DWASA failure____________________			
Discrimination between VIP and other areas			
Electricity failure; load shedding			
Lack of monetary support for DWASA			
Water pollution in and around Dhaka City			
Lack of policy support and implementation by the Government			
Others (specify)……………………….. …………………………………………….			

A.11 Did you have to take any measure from your own side to get water from DWASA (piped water supply)?

- Structural____
- Non-structural____
- Bribery ____
- Others ____

A.12 How do you cope with the situation when you don't have water?

Do you need to buy water from WASA (not piped water)?

☐ Yes ☐ No

Do you need to buy water from other sources than DWASA?

☐ Yes ☐ No, if yes then name the source_________________________________

D. Willingness to pay survey

B.1 How much water does this business use on a daily basis? (Approximately)

…………………………………………………………………………………………….

B.2 Do you pay your WASA bills regularly? Is your bill based on meter reading?

☐ Yes ☐ No ☐ Yes ☐ No

B.3 How much do you pay for your monthly water bill? (in TK)

☐ ☐ ☐

100-200 200-300 300-400 ☐ 400-500 ☐ More than 500

B.4 In your opinion, for what reasons do you pay water bill for?

☐ Cost recovery ☐ Maintenance ☐ Operational work ☐ Staff payment

B.5 How do you consider your present water tariff?

(Strongly Dissatisfactory (Tariff too high) =1, Dissatisfactory (High) = 2, Neutral = 3, Satisfactory (Fair) =4, Strongly satisfactory (Under priced) = 5)

☐ Strongly satisfactory ☐ Satisfactory ☐ Neutral
☐ Dissatisfactory ☐ Strongly Dissatisfactory

B.6 If your water bill increases 10% of what you are paying right now, what will you do? (Significantly = 75%, a lot=50%, moderately= 25%, a bit= 10%, none= 0%)

☐ Reduce use significantly ☐ Reduce use a lot ☐ Reduce use moderately
☐ Reduce use only a bit ☐ Reduce none

B.7 If your water bill increases 25% of what you are paying right now, what will you do? (Significantly = 75%, a lot=50%, moderately= 25%, a bit= 10%, none= 0%)

☐ Reduce use significantly ☐ Reduce use a lot ☐ Reduce use moderately
☐ Reduce use only a bit ☐ Reduce none

B.8 If your water bill increases 50% of what you are paying right now, what will you do? (Significantly = 75%, a lot=50%, moderately= 25%, a bit= 10%, none= 0%)

☐ Reduce use significantly ☐ Reduce use a lot ☐ Reduce use moderately
☐ Reduce use only a bit ☐ Reduce none

B.9 Will you consider paying more for continuous (24 hrs/day) piped water supply?

a) 10% more b) 25 % more
c) 50% more d) 100% more

B.10 In case of water unavailability or shortage, what measures you will take?

a) Buy water from DWASA
b) Reduce use in quantity
c) Reduce business hours
d) Fire employees
e) Reuse waste water
f) Use water saving technology

Others ____