DISSERTATION

URBAN WATER SUPPLY IN TANZANIA: THE CASE OF HAI WATER PROJECT IN KILIMANJARO REGION AND DAR ES SALAAM CITY

Submitted by
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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY WANDE SINDILLA JOSHUA REWETA ENTITLED "URBAN WATER SUPPLY IN TANZANIA: THE CASE OF HAI WATER PROJECT IN KILIMANJARO REGION AND DAR ES SALAAM CITY" BE ACCEPTED AS FULFILLING IN PART THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF THE DISSERTATION

URBAN WATER SUPPLY IN TANZANIA: THE CASE OF HAI WATER PROJECT IN KILIMANJARO REGION AND DAR ES SALAAM CITY

Urban water supply and sanitation services have captured the world attention for several decades. While experts around the world agree that an adequate provision of this resource is crucial for the well being of the people, the demand for it, particularly in developing countries has always surpassed its supply. Where water supply projects has been constructed, issues of equity, efficiency, cost recovery, sustainability as well as whether or not beneficiaries are willing and able to pay for service improvements have been raised.

In this study, sustainability is addressed by evaluating equity in water delivery in terms of the distribution of public taps among different villages and townships in the Hai Water Project Area - Kilimanjaro Region, comparing inter-temporal and intra-temporal billing collection efficiency between households and public tap consumption in villages and townships as well as comparing revenue from bills collected to the operations and maintenance costs of the project. The results from this study show that public taps are unevenly distributed among beneficiaries. Performance in bills collection is better for the public taps than for household connections, and overall, townships' performance is better than that of villages.

Water supply performance in Tanzania is assessed by evaluating equity and efficiency aspects of urban water supplies in the city of Dar es Salaam in terms of the amount of water supplied to different districts and Dar es Salaam Water and Sewerage Authority (DAWASA) branches. The study concludes that the city is faced with an acute water supply problem, water is unevenly distributed at all levels and that inequality between and within districts is likely to increase over time.

The study also estimates the Willingness to Pay for improved water supply (quantity) in the city of Dar es Salaam as well as the premium that residents are willing to pay for quality improvement. Results show that households in the city are willing to pay on average Tsh. 2,685 over and above their current monthly water bill for improvement in water supply (quantity) and Tsh. 537 over and above the amount for supply improvement as quality premium.

Lastly, the study estimated the benefits of increased potable water supply for the city of Dar es Salaam. A Marshallian partial analysis is used to estimate consumer and producer surpluses arising from such an improvement. Results show that the net benefits to both consumers and producers is positive.

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DEDICATION

To My parents: The late Hoi-Ngaya-Yako, Elisa Maacha (*Mama-yoo*) and my father Joshua Sindilla Stephano Lyimo (*Baba-yoo*). To My Daughter Bim W. Reweta and My Sons: Wande Ngitanamsu Joshua, Wande Mathias Oko.

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CHAPTER ONE

URBAN WATER SUPPLY ISSUES IN DEVELOPING COUNTRIES

1.1 Introduction

The provision of adequate supply of water and sanitation services in the urban areas of the developing countries is crucial for the well being of the people (Reweta and Sampath, 1999). Over time, the demand for water and sanitation services in developing countries has been increasing as a result of the raising standards of living that occur with economic development, the population increase resulting from natural growth as well as rural-urban migration, rising per-capita income, increasing awareness of the health implications of not having the service and greater demands on the family labor in the new economic settings. Adequate water supply in general, is therefore vital for the survival and development of every society.

As a result, efforts have been made by many developing countries to supply potable water to both the urban and rural communities as a means to enhance rapid socio-economic development. Many water policies have been developed in different countries outlining the level of services to be attained or provided. Objectives have included provisions of potable water for all by a specified date, ensuring that water supply is not more than a certain maximum distance from every household, etc.

The costs associated with these plans are enormous. In many cases the developing country in question will develop the plans and start looking for donors and or financial resources to implement them. These efforts have by and large been overrun by uncontrolled population growth in both urban and rural areas. The case of urban areas is even more complicated by the rural-urban migration.

In the recent past however, the policy context for water resources has profoundly changed. The emphasis of policy makers has shifted from playing the role of planning the physical provision of water resources i.e. identification, design, appraisal and implementation of projects to that of managing water resource systems. Governments have shifted emphasis from being a provider of water resources to being a promoter, facilitator and a creator of an enabling environment for others to provide water resources. This chapter summarizes issues that have repeatedly appeared in economic literature on urban water supplies and sanitation services in developing countries.

1.2 Equity and efficiency

Despite their importance, equity and efficiency in urban water supplies in developing countries are topics that have not received adequate coverage in economic literature.

1.2.1 Equity

In any urban setting, population size differs from one area to another and so should water supply distribution (Reweta and Sampath 1999). Population dynamics i.e. the natural rate of growth and rural-urban migration affects population density in urban centers. It is common knowledge for example that poor households tend to have larger families than rich households. As such population in poorer neighborhoods will increase faster than that in rich neighborhoods. This situation is worsened by the fact that when rural-urban migration occurs, the new immigrants settle in the poor neighborhoods first before they can move to other areas of the city if they ever will. This rapid urbanization coupled with lack of financial resources has made it difficult for urban planners to respond to growing demands for sanitation infrastructure. The informal squatter settlements that surround many cities often lack piped water or any kind of wastewater disposal, making residents prone to high rates of diarrhea and other diseases. The epidemiological evidence from developing countries indicate that, taken together, improvement in hygiene and excreta disposal and ensuring a sufficient quantity of water close to the home environment e.g. in-house tap or one on the premises, have a larger impact on human health than improvements to the quality and availability of water alone (Krauss and Boland 1997).

Equity can also be looked at from the incidence of a disease outbreak point of view. When water related disease outbreak occurs the incidence falls directly or more heavily on the poor. As a group the poor lose more working days per year due to water and sanitation related diseases and illnesses as compared to those living in more affluent areas. Suffice is to say that the demand for potable water and sanitation services increases much faster in poorer areas of the city than in the affluent areas. It is therefore important for planners and policy makers to put these issues into perspective whenever improvements of water supply systems take place. This will enable economies to save on resources as will be discussed later in this chapter.

Inequality can also be looked at from public policy point of view. Public financing for water and sanitation services in developing countries (mostly in terms of subsidies) are justified by the claim that the poor have a low ability to pay for services. In practice however, it is the rich who end up benefiting disproportionately from subsidized water and sewerage services. Heavy subsidization of these services has also been blamed for the slow expansion of service partly because of constraints on public financing and also because of inefficiencies in the use of available resources. The situation is made worse by the lack of accountability by the supply organizations to their consumers. In the final analysis, it is the unserved people particularly in the urban areas who pay higher prices than the served (Briscoe and Garn 1995).

In the city of Dar es Salaam in Tanzania the unserved population who depend on water vendors for their water supply pay as much as 16 times the price paid by households with piped water connections (Kjellen, undated). Other studies have shown that, in some peri-urban areas in developing countries the poor are forced to pay as much as 35 to 40 percent of their incomes to buy water[1].

The above picture calls into question the use of subsidies in urban water services and in some cases removal of subsidies has been recommended. However, the removal of subsidies does not address the problem of capital mobilization for projects in poor areas (Gourisankar and Ashok 1995). The fact that the poor are already paying more than the rich for the water that they use does not mean that they are actually able to pay. One needs to take into consideration the opportunity cost of such payments in terms of what the households will have to forgo in order to be able to use water. Such essentials will

[1] Footnote in Gourisankar et, all. 1995

include education, food, nutrition etc. which has a very significant impact on the health and wellbeing of the households. Gourisankar and Ashok maintain that the rich get subsidized and therefore benefit more in part because subsidies have been channeled through institutions which have provided financing priorities to service rich urban areas. They argue that a blanket removal of subsidies from the poor on these grounds will be unjust and conclude that subsidies are still necessary for the poorer areas but should be better targeted.

Inequality in consumption of water supply is also critical. The social structure in many third world cities give rise to water consumption pattern that lends itself to divisions based on social-economic status of the household. In the city of Dar Es Salaam for example, there are three distinct types of services based on the availability of water connection on the premise of the consumer namely household connection, yard connection and no connection (JICA 1991). These service levels determine the levels of water consumption in the city and can conceal very high levels of inequality in water consumption by households. The JICA report classified household connection into high, middle and low consumers. With this classification, 5 percent of the population (high consumers) consumed 22 percent of the available domestic water supply in the city, 2 percent (middle consumers) consumed 5 percent, and 25 percent of the population (low consumers) consumed 42 percent of the available water supply. In total, 32 percent of the population (those with household connections) consumed 69 percent of the available domestic city water supply while 24 percent of the population (depending on yard connections) consumed 21 percent of the water supply. Those with no connection (depend on kiosks and stand pipes) representing 44 percent of the population consumed only 10 percent of the supply.

1.2.2 Efficiency

Efficiency in urban water distribution and delivery system is also crucial. Efficiency can be discussed under four situations - the first two pertaining to the short run, the third to medium run and the fourth to the long run (UN, 1980, Seagraves and Easter, 1983; OECD, 1987; and, 1988 in Sampath 1992).

The first situation refers to cases where the available water for urban use - both domestic, industrial and institutional is limited. The objective in such a situation will be to maximize the net benefit to society, which can be attained by equating the social marginal value (SMV) of urban water supply across these different user groups. In cases where these social costs are not equalized, reallocation of water between user groups could increase the net social benefits (NSB).

The second situation occurs when the water authority is faced with the problem of deciding whether or not to increase water supply from a particular system. Such a decision will involve an opportunity cost, which must be factored in the decision i.e. at the margin, the variable costs that will be incurred to increase urban water supply will not be available for use elsewhere in the economy. Such a decision can be economically justified only if the marginal social benefits (MSB) exceed the marginal social costs (MSC), with an optimal increase occurring at the point where the MSC equal the MSB.

The medium term situation is one where a water authority is contemplating expansion of the delivery system and an allocation of capital resources is required to construct a new water supply system. At the margin, such additional investments will be warranted only if the social returns exceed the social costs involved.

The fourth situation is long run in nature. The problem here is one of deciding what should be the optimal level of investments in urban water supply vis-à-vis investments complementary to or substitutes for the use of water i.e. water conservation projects or technologies that will conserve household, industrial and institutional water uses.

At the minimum, efficiency can be looked at as the ability of a water authority to reach and maintain a given water supply target at the lowest possible cost. This will include the ability of the water authority to have both short and long-term targets that puts into consideration changing demands and population dynamics and to sustain itself. A negative deviation from such a target will reflect a measure of inefficiency in the system, which will serve as a signal to the water authority to look for better ways to reach their supply target. Such a measure will also allow comparison of performance by different geographic areas to be done to determine where to concentrate resources and efforts. In developing countries where such resources are scarce the importance of this issue cannot be understated.

The efficiency with which financial resources are used in most developing countries is also highly questionable. In their article on financing water under agenda 21, (Briscoe and Garn 1995) points out that only four countries - Singapore, Republic of Korea, Tunisia and Botswana have water and sewerage utilities that reach acceptable levels of performance. Inefficiencies noted include underutilization of installed capacities (only 130 connections made to a sewerage system designed to serve 2000 connections in Accra Ghana), unregistered connections (30% in Caracas and Mexico city), unaccounted for water (8% in Singapore, 58% in Manila and around 40% in most Latin American cities) and unacceptable high number of employees per 1000 water connections (while 2-3 in Western Europe and 4 in well run utilities in developing countries, it is between 10 and 20 in most Latin American countries). They concluded that the vast majority of water supply agencies in developing countries are high cost, low quality producer of services.

Such inefficiencies has lead to inability of the formal water and sanitation organs to provide the required service levels in their respective areas of service and has given rise to a parallel market for these services. In the city of Jakarta, Indonesia for example, only 14% of the residents receive piped water directly as compared to 32% getting their supplies from street vendors and 54% from private wells. (Briscoe & Garn 1995). In the city of Dar es Salaam, Tanzania, about 30% of the households have house connections, 24% yard connections and 45% had no connection - forced to rely on kiosks and stand pipes (JIC A 1991). Although there may be cases where the parallel market can provide the service efficiently, in most cases the service is offered at exorbitant prices. This price differential should be a clear signal to the formal sector of an opportunity to expand service at a reduced cost for all.

Inefficiency can also be assessed in terms of the ability of the utility to collect bills, water delivery and leakage. The loss of water through leakage is estimated to be as high as 40% in some developing countries. In Cairo Egypt for example, readings of one vacated building over one weekend showed that over 75% of the water was lost through leakage. Similarly in China's 600,000 kms of underground pipes, $ 360 m worth of water is lost each year though leakage. If 1% of this amount is saved, it can supply 6.5 m people with water for one year (Financial times July 30, 1996, in Nigan 1996).

1.3 Pricing and cost recovery

Inadequate cost recovery policies and practices have been cited in literature as the most severe constraint to the development and maintenance of a sustainable water supply system. In many urban areas in developing countries for example, cost recovery is only about 30% (Nigam 1996). It has been argued that developing countries put emphasis on the implementation of water projects with donor support while the operation and maintenance (O&M) of the existing projects has often been neglected. Water pricing is done with little or no relation to the O&M costs of the water authorities. The result of this practice has been the deterioration of water supply services, inadequate repair and maintenance, frequent interruptions, lack of capacity to expand service under increasing demand, poor quality water supply, lack of treatment of waste water and increased water scarcity.

This practice has been very costly to water users. In many cases they end up not receiving enough water or receiving poor quality water supplies. In turn they are forced to incur extra costs to treat water before use, (i.e. boiling, chlorination etc.), construction of expensive storage facilities at their premises or going long distances in search for water increasing the chances for contamination and therefore jeopardizing their health situation. In low-income communities, particularly the squatter settlements around large cities, facilities for proper disposal of human waste are seldom available. Hygiene practices are generally poor and water for household use is often inconvenient and contaminated.

The practice of cost recovery on the other hand require the technical and administrative ability to operate an effective pricing system (Gunnerson 1991, Bahl & Linn, 1992 and Ostrom et al., 1993 in Krauss & Boland 1997) and a pricing system preferably involving metering of each customer (Krauss & Boland 1997). The aim of such a pricing system should be to recover the full costs of supply including operation and maintenance costs, administration and capital costs. According to Krauss and Boland, the government role will be to enact policies that will facilitate the autonomous operation of local water utilities. Such policies should include legislation that will: (1) enable utilities to function independently and assume local responsibility (2) eliminate political interference in the operation of local utilities (3) provide and enforce regulations for oversight and protection of consumers and (4) work for the development of in-country financing independent of external support agencies.

The relationship between the cost of providing a service and the price paid for the service has major implications for the technical and financial performance of supply organizations, and the relationship of such organizations and the users it serves (Briscoe & Garn, 1995). While for example, urban water consumers in most industrialized countries pay all recurrent costs for operations, maintenance and debt service for both water and sewerage services as well as most of the capital costs, consumers in developing countries pay far lower proportions of these costs i.e. about 35% of the average cost of supply for water (Garn in Briscoe & Garn 1995). The gap between costs and prices is highest in Africa and Asia where service reliability and sustainability is the weakest (Briscoe & Garn 1995).

Nigan (1996), calls for the design of a comprehensive mechanism for meeting the capital costs and recovering the operations and management costs of water supply associated with the provision of water and sanitation services taking into account equity, efficiency and effectiveness of resource use. He argues for empowerment of communities both socially and economically to take care of and improve their services. He asserts that cost-sharing in terms of labor and in-kind contribution of capital and recurrent costs of basic level service while taking into account the willingness and ability to pay as well as recovery of full capital and recurrent costs for higher levels of service should be adopted to extend basic service and ensure sustainability.

The basin management approach is also important in the pricing of water services if water is to be treated as an economic good. According to Gleick 1993, only 8% of fresh water resources are used for domestic purposes, 23% for industry and 60% for agriculture (Nigam, 1996). In many countries, the two major users i.e. industry and agriculture, pay little or no charge for its use although their use impacts the availability and cost of drinking water supply. The demand pressure from agriculture for example, affects a wider group of people than those at point source in terms of stress to supply of drinking water, environmental degradation, water quality as well as lowering of the water table. If water is to be treated as an economic good, its pricing and cost recovery should take these dimensions into account more explicitly. Equity in tariff policy is also a key factor particularly where you have areas that have been saved for long periods and areas that have not. On one hand the historic cost of the infrastructure associated with the former are very low and has little impact on tariffs while on the other hand the replacement costs are very high. In such cases, calculating water tariffs on the basis of current value of the infrastructure would help in restraining growth of water consumption as well as generate funds for basic investment needs (South Africa 1994, in Nigam 1996).

Financing of water and sanitation services should also be looked at in a wider context of poverty eradication, without which the concept "water has economic value" will fail to serve as a basis for sustainable financing strategy.

1.4 Beneficiary participation

One of the guiding principles enunciated at the 1992 pre United Nations Conference on Environment and Development i.e. the Dublin Principles was that, water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels, with decisions taken at the lowest appropriate level (Briscoe & Garn 1995). The importance of such an approach in water projects is well documented in literature. Reweta and Sampath (1998) noted that beneficiary participation both in kind through involvement in planning, labor contribution in project implementation, and cash payment towards operations and maintenance of the project are key to sustainability of a water project. Nigam 1996 noted that cost recovery mechanisms are most successful when there is community participation in their design, implementation and management attributes that are always neglected in the desire to set up institutional structures.

Also noted, investment in the water and sanitation sector should be demand driven i.e. households should be provided with services that they want, and are willing to pay for (Whittington at, all. 1998). Both approaches calls for beneficiaries to be involved in decision regarding desired service levels, and an understanding of the cost recovery implication of their choices. This is a new approach compared to the one where historically water and sewerage projects in developing countries have been characterized by a top-down planning approach that principally involved government officials and consultants of the external support agencies. Beneficiaries of the project and other stakeholders are rarely consulted and in poorer communities they are ignored (World bank, 1996 in Krauss and Boland 1997).

Most urban households regardless of income levels desire affordable water and sanitation services. It is well documented that even the poor in developing countries are frequently willing and able to pay the full cost of a potable water supply (Crane, 1994, Okun 1991 in Krauss and Boland 1997). Also, in most studies done in major cities in developing countries, monthly water expenses are a much larger share of income and often larger in absolute terms for the poor as compared to the wealthy i.e. low income households spend 18 percent of their incomes on water during the dry season as compared to 2-3 percent for the upper income households (Whittington et al 1991). Other recent studies on water vending activities support this finding. It has been shown that the poorest households in Port-au-Prince Haiti sometimes spend 20 percent of their income on water during the dry season (Fass 1988, in Whittington 1991), while an average household spends about 9 percent of its income on water from vendors in Ukuda Kenya (Whittington, 1990). Communicating and providing information to the consumers is usually necessary to raise public awareness regarding the importance of sanitation to public health and the value of water. Informed consumers are more likely to be willing to participate in programs designed to improve their lives. In this regard, both government and non-governmental organizations can play a major role as providers of information to the public stressing the partnership role required of the consumers and the public at large.

On this subject, the issue of gender imbalance has also been noted (Michael, 1998). In many developing countries women predominantly perform the role of fetching water and the activities required for making it safe for household uses. In many cases such activities are also considered a woman's social responsibility. However, the number of women involved in the planning, design, decision making and implementation of water projects at all levels is very small compared to their male counterparts. Given their central role in water supply to their households, it should be natural that women participation be emphasized as they are the one's most affected when water is not available.

1.5 Financing issues

The appropriate financing mechanism for water and sanitation services is a topic widely discussed in economic literature. While most authors agree on the need for sustainable financing arrangements, there has not been a general consensus on how to attain such an arrangement.

Water, as an economic good with economic value in all its competing uses is a principle that is increasingly being widely adopted. This consensus has been used as a central principle governing the financing of water supply and sanitation services i.e. from both efficiency and equity point of view, private financing should be used to finance private goods and public finance be used to finance public goods. This principle is based on the belief that individual social units, from households to a whole river basin are in the best position to weigh the costs and benefits of different service levels and therefore investment levels of resources for benefits accruing to that level of social organization.

The economic costs of providing water service include two main components i.e. the financial costs of abstracting, transporting, storing, treating and distributing the water and the economic cost (scarcity value or the opportunity cost) of water as an input. On the benefit side, one can list several different benefits arising from water supply to a household. These include convenience, time saving, and amenity benefits arising from the health benefits it offers. Since these benefits are private to the household, public finance allocation principle will dictate that most of the costs associated with such supplies be borne by the household itself. It is argued that such a system will enable households to make appropriate decisions on the type of service that they want – whether a communal tap, a yard tap, or a household connection with multiple taps. Water user costs should therefore cover all the economic and scarcity cost of water (Briscoe and Garn 1995). The idea here is that providers of drinking water should strive to become financially self-sufficient and relatively autonomous entities that can collect revenue from customers sufficient to maintain and expand system services as needed.

The appropriate financing of sanitation, sewerage and waste management is even more complicated because the benefits perceived at the individual household are different from those at a larger aggregate society. Individuals are more willing to pay for services that directly benefit their family and property and less willing to pay for services that they do not have such a direct benefit.

The fundamental axiom of public finance dictate that costs associated with this service should be allocated to different levels according to benefits accruing to those levels. At the lowest level for example, a household should pay the bulk of the cost incurred in providing on plot facilities - bathrooms, toilets and on plot sewerage connections, while at block level, residents of the block will collectively be required to pay the additional costs associated with the collection of wastes from individual houses and transporting it to the boundaries of the block. The neighborhood level on the other hand will take care of the incremental costs to its boundaries or treating the neighborhood wastes. Similarly, residents of a city should collectively pay the additional costs incurred for in collecting and transporting city wastes to the city boundaries or treating it. At the basin level, all stake holders - cities, farmers, industries and environmentalists should collectively assess the value of different levels of water quality service within the basin and decide what quality they are willing to pay for, and on the distribution of responsibilities for paying for the necessary treatment and water quality management activities.

In reality though, a number of issues need to be considered in the above financing arrangement. The transaction costs of collecting revenue at different levels and the spill over effect of the benefits from one level to another i.e. the externality component of providing the service are some. At the national level for example, a nation, as a whole will benefit through the health implications of wastewater management, which gives this service a public good character.

It is difficult and not useful to make the distinction on the private and public nature of water supply and sanitation (Nigam 1996). He argues that safe and clean water supply and sanitation provide a number of health benefits, which have a positive externality on society as a whole. However, health benefits are not the only reasons for the state to provide these services. Reducing the time women spend fetching water allows them to engage in other economic activities that contribute to the economy at large (Reweta & Sampath 1998), and take care of children (Nigam 1996). Provision of adequate water supply will also reduce the time girls spend in fetching water allowing them more time for schoolwork. Girls' education yields a higher rate of return than any other investment in developing countries (Summers 1994, in Nigam 1996). Educating girls has large social benefits in terms of saving from improved hygiene and birth control as educated women choose to have fewer children. Bringing water closer to home and reducing the time girls have to spend fetching water therefore has an externality that accrue to society as a whole. Nigam, also points out that water supply closer to home allow environmental considerations to be built into the user charges more effectively. The analysis based on the private/public nature of the good may not provide clear-cut answers because of the difficulties in assigning the marginal private and social costs and benefits. He concludes that community management of the water environment may be a better starting point for the design of both environmentally sound policies and strategies towards water supply and sanitation as well as a sustainable financing mechanism.

In any case, the success of any financing arrangement should embrace economic efficiency and environmental sustainability. It should follow a demand driven approach in service delivery, i.e. recovering the full cost of the private services that people want and are willing to pay for (including water supply and collection of human excreta and waste water). Scarce public funds should be used to fund only those services that provide wider communal benefits such as the disposal and treatment of wastes.

Lastly, institutions providing these services must be flexible, responsive and financially sustainable, allowing a larger role for community organizations and private sector participation (Briscoe and Garn 1995). According to Krauss and Boland, private sector participation may range in form and degree from simple service and management contracts for a defined activity (e.g. maintenance or bill collection) to complete divestiture, where a private firm purchase assets from the government and assume full control. Successful private participation and community-based options can deliver a number of benefits. These include meeting consumer demands at lower costs, removing the need for government subsidies, assisting in capital formation, and prompting economic efficiency and development. The success of such participation would require sound policy governed by relevant laws and regulations that are adequately enforced. This pre-condition would necessarily call for the strengthening of the government and local institutions as well as the recognition on the part of the existing public water and wastewater institutions of the fact that poor communities are an integral part of their customer base. Sustainable financing therefore needs to be developed in conjunction with mechanisms for community participation, management and cost sharing.

1.6 Water quantity, quality, sanitation and health implications

It has been observed that, throughout the developing countries, municipal and industrial wastewaters are rarely treated prior to disposal (Krauss & Boland 1997). Urban streams, rivers and estuaries are severely polluted with human pathogens and toxic wastes. Dirrhoeal and respiratory infections that results from these conditions continue to be among the most frequent causes of sickness and death among infants and children.

At the end of the International Drinking Water Supply and Sanitation decade, despite the worldwide efforts to deliver water and sanitation services, 1,800 million people were still without access to sanitation services and nearly 1,300 million lack access to safe drinking water, in large part because population growth wiped out progress achieved in these areas. Rural-urban migration in developing countries also surpassed the ability of many developing countries to provide services (Peter H. Gleick, 1993).

It was also predicted that if the trend in coverage for water supply and sanitation that prevailed during the International Drinking Water Supply and Sanitation Decade continued in the 1990's, almost 1 billion people will still be without access to clean water and 2.2 billion without adequate sanitation at the dawn of the 21 century an equivalent of 20 and 40 percent of the population in developing countries respectively. Despite rural-urban migration over 75 percent of these people will still be living in the rural areas (UNICEF, 1995 in Nigam, 1996).

Over one third of all deaths in developing countries in recent years were children under five years old (Gleick 1993). In most developing countries diarrhea is the primary cause of death among these children, a direct result of inadequate sanitation and water supply. Other water-related deseases including malaria, schistosomiasis, onchocerciasis and cholera continue to be responsible for hundreds of millions of cases of disease, and millions of death every year (Gleick, 1993). This gloomy picture is an indication of how much still has to be done in order to provide adequate services and eradicate the diseases that go along with poor water and sanitation services.

Water is also generally accepted to be a vehicle for disease transmission under certain circumstances and must be properly controlled from a public health point of view (Chanlett in Legals, et. all. 1997). It has also been noted that public health control over water supplies in developing countries is often not sufficient to protect communities against disease (UNEP, in Legals, et. all. 1997). Other literature points out that when water is too scarce, people tend to ignore the quality aspect of it and concentrate more on the quantity, which again increases the chances for disease. Even when a community is supplied with treated piped water it does not necessarily mean that water related diseases would be totally eliminated. Piped water can still be contaminated through low pipe pressure and breakdown in the network system. The situation is made even worse when water has to be hauled from a source far away from a household and then stored in containers at home. This will be the likely situation when standpipe or a public tap is the main source of water supply; water is rationed or bought from vendors. Water used from containers at home is not of the hygienic quality one would expect from a well-controlled source of in-house running water. Methods of transport and handling stored water including unhygienic containers are more likely to cause diarrhea in households subject to such system. Systems water supply through of stand pipes (and vendors) force haulage and or storage of water in containers by households - a conducive condition for enteric disorders for consumers (P.Jagals et. all. 1997).

The costs of such a system to the individual, household and the nation at large are enormous. These costs are in terms of social disruptions, lost economic opportunities, and health costs. The most defenseless and economically marginal segments of society are usually the most susceptible and therefore suffer the greatest (Pegram, et, all. 1998).

In many developing countries, millions of dollars are spent every year to treat outbreaks of diseases most of which are water related. Such expenditures are looked at as part of the budget of the ministry of health or any other responsible ministry. But for countries that are faced with chronic deficits in financial resources this business as usual attitude is a luxury that cannot be afforded. Countries need to quantify the cost of treating water related diseases every year and compare it to the cost of improving water and sanitation services which will in turn reduce the occurrence of such diseases. Such cost comparisons will provide the needed incentive for governments to allocate more resources to water and sanitation services, which in a long run will prove to be a saving.

Only one study has been done in an attempt to quantify the cost of diarrhea in Africa (Pegram et, al. 1999). The study concluded that diarrhea disease claim about 43,000 people every year in South Africa, that one in every 14 people require formal treatment for diarrhea every year and that the annual public and private direct health care costs incurred due to the disease are at least R3.0bn. The total social cost of diarrhea disease was estimated to be at least 1 percent of the country's GDP i.e. R 3.4 bn an equivalent of $ 0.567bn[2]. Most developing countries particularly in Africa cannot afford to commit such resources on an annual basis. Also, in most developing countries characterized by chronic balance of payments (BOP) problems, with medicine mostly being an imported item, reducing the incidence of illnesses will help reduce the demand for such medicines and thereby easing the BOP problems facing the developing country in question. Under such circumstances the quantification of these costs will provide a crucial motivation to guide budget allocation in improving water and sanitation services.

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[2] R6=US$1.

It has been argued that the demand for water supplies and sanitation services follow each other in a sequential manner, i.e. only when the poor have adequate water services will they develop a strong demand for sanitation services (Briscoe & Garn 1995). Adequate water supply provision is therefore a pre-condition for demand for sanitation services.

1.7 Other issues

The above issues are not the only problems facing the water supply and sanitation services in developing countries. Other major issues include manpower and institutional constraints, lack of recruitment and training, poor emoluments and remuneration packages, lack of performance evaluation criteria and lack of spareparts and equipment.

According to a mid-decade review of the World Health Organization, insufficiency in trained personnel both at professional and sub-professional levels were listed as respectively the third and the fifth most serious constraints to major achievements in the water supply and sanitation in developing countries (Pickford 1991, in Areola, et, all. 1997). Lack of skills or knowledge, motivation, incentives and attitudinal causes have also been listed as the most usual causes of deficiencies in human performance in the water sector (Carefoot 1987 in Areola, et, all 1997). The review of the International Water and Sanitation Services in the developing countries of Africa, Asia and Latin America also indicate that despite progress, the water sector was still faced with outdated policies, inadequate institutions, shortage of well trained manpower at all levels, inappropriate technology, and ineffectual financial mechanisms (Hartvelt and Okun 1991, in Areola 1997). There is currently no indication or reason to believe that this situation has significantly changed.

In a study done in Nigeria (Areola, et, all. 1997), the proportion of staff in water agencies with primary education or less ranges from 45 to 86 percent. Those with college certificate and above range from 6 to about 14 percent. This situation is made even worse by the tendency to concentrate the few available high caliber personnel in the headquarters where they perform mostly administrative duties and get bogged down in bureaucracy.

Although staff recruitment and training in Nigeria like in many other developing countries is highly constrained by shortage of funds it has also been argued that the low educational base of the employees make them unsuitable for training / retraining programs. In a situation where the majority of the employees are uneducated or have very little educational background, this can be a very serious constraint in improving services. Recruitment of better-educated people is difficult given the poor remuneration's given by some of the water utilities. Allowing autonomy to the utilities may help solve this problem as it will enable setting of competitive packages, setting of realistic user fees and create a motivation for its collection.

There is a general lack of performance appraisal system for individual departments and the water agency as a whole in many developing countries. In most cases there is no laid down procedures for target setting, job description, and performance evaluation of the water organizations and their various subdivisions. (Areola, et, all. 1997, Reweta and Sampath 1999). Billing collection rates for example, can be one performance indicator of how a utility is doing. Setting benchmarks for collection rates will provide guidance for the utility as to when to increase collection effort. There is also a need for water agencies to draw up master plans to ensure an efficient and coordinated development of water supply and sanitation in the light of projected growths and changes in population and in economic activities.

This work will focus on equity, efficiency and cost recovery as they pertain to a small water project in Kilimanjaro region in northern Tanzania as well as equity and efficiency in water delivery for the city of Dar es Salaam. The willingness to pay for improved water quantity and quality as well as the benefits of increased potable water supply for the city of Dar es Salaam will also be estimated.

1.8 The Objectives of this work

The objectives of our paper are:

1. to evaluate equity in water delivery in terms of the distribution of the public taps among different villages and townships in the Bomang'ombe-Uroki water project in Kilimanjaro region (Northern Tanzania)
2. to compare both inter-temporal and intra-temporal billing collection efficiency between household and public tap distribution systems for both villages and townships, and between the townships and villages
3. to compare revenues from bills collected to the Operation and Maintenance (O&M) costs
4. to evaluate equity and efficiency aspects of urban water supplies in the city of Dar es Salaam in terms of the amount of water supplied to different districts and DAWASA branches and suggest ways to improve the situation

5. to explore peoples perception of both the quantity and quality of potable water supply in Dar Es Salaam and their support for policies that will support increased quantity and improved water quality
6. to determine factors that influence the willingness to pay for increased potable water supply in the city of Dar Es Salaam
7. to determine the WTP for increased supply; as well as the premium that they are willing to pay for improved water quality
8. to assess the influence of the gender of the household head on WTP, and
9. to estimate the benefits of increased potable water supply for the city of Dar es Salaam.

1.9 Organization of the study

Chapter two investigates a small rural/urban water supply project in Tanzania in terms of equity, billing collection, cost recovery and beneficiary participation and evaluates its potential for further improvement. Equity in public taps distribution is analyzed using the Theil's information theoretic measure while the performance in monthly water bills collection is evaluated using the Theil's forecast error method.

Chapter three evaluates performance of urban water supplies in the developing countries. The chapter will analyze equity and efficiency aspects of performance evaluation of urban water supplies using the city of Dar Es Salaam in Tanzania as a case study. Equity and efficiency, between and within the three administrative districts in the city, the five Dar Es Salaam Water and Sewerage Authority (DAWASA) branches and wards will be analyzed.

Chapter four explores peoples' perception of both the quantity and quality of potable water supply in the city of Dar Es Salaam and their support for policies that will support increased water supply and improved water quality. Willingness to pay for increased water supply is estimated using the maximum likelihood method. Factors important in determining willingness to pay for increased water supply are identified.

Chapter five attempts to measure benefits that may arise from increased water supply to the city and its distribution in terms of the consumer and producer surplus. Chapter six provides an overall discussion of the results of the previous chapters and summarizes the conclusions and policy recommendations for development of the water sector in Tanzania.

CHAPTER 2

SUSTAINABILITY OF A WATER SUPPLY SYSTEM: THE CASE OF HAI WATER PROJECT IN TANZANIA.

2.1 Introduction

Adequate portable water supplies for both rural and urban areas is crucial for the well being of the people for drinking, cooking, cleaning, washing and bathing. As an economy develops, people demand a more systematic and reliable water delivery systems at their disposal. This is partly because of the increasing awareness of the health implications of not having the service and partly as a result of greater demands on the family labor in the new economic settings. The roles of women in society also change as they participate more in the direct raising of the output of the economy as a whole. The demand for their time both for the family and for themselves becomes critical.

In many developing countries, the role of fetching water and the activities required to make it safe for household uses are predominantly performed by women. With economic development the need to minimize the time spent on these activities is critical. The provision of reliable water supply services will therefore not only reduce the time spent on water but also free labor that can be used in other economic activities.

Such a supply system cannot be easily provided unless there is a mechanism that can properly develop and maintain it. This requires resources both in cash and in kind. The issue of resource in kind is particularly important in the developing countries context where labor may not be fully employed, and where people may not have the monetary financial resources but may have non-monetary items/wealth they can contribute to water supply projects. Contribution in kind in this chapter is defined broadly to include physical labor contributions as well as contributions of non-monetary wealth that can be sold for money. Knowing the potential time savings that will come about with the project, villagers will be willing to contribute a part of that labor to the project as part of their participation.

The other critical resource is the cash involved in the projects. Experience has shown that total subsidization of projects puts a heavy strain on government budgets that ends up negatively affecting development of the water sector. Also, it has been shown that, when people are made aware of the benefits that they will receive from a water project, they are willing to participate in contributing to the financial costs of running the projects which is critical for the sustainability of a project.

This chapter will show an example of a rural/urban project in Tanzania, in which participation both in kind through beneficiaries involvement in planning, labor contribution in project implementation, and cash payment towards operations and maintenance of the project is taking place. The chapter will also evaluate the project performance and suggest ways that can be used for improvement.

2.1.1 The project

The Hai District Water Project came into being after a conclusion of an agreement between the Federal Republic of Germany and the Government of the United Republic of Tanzania in 1989. The objective of the project is to provide adequate, clean, hygienically safe potable water and improve the hygiene situation of a major part of the rural population of Hai district.

The project area covering five villages (Kyeeri, Shari, Mamba, Uswaa and Roo) and three townships (Kwasadala, Kambi ya Nyuki and Bomang'ombe) is located on the southwestern slopes and foothills of mount Kilimanjaro between altitudes 900 to 1800 m above sea level. The area lies within the cultivated zone and borders the rain forest belt at an altitude of above 1800m to the north. The focus group in the project area mainly consists of smallholder farmers growing coffee, banana and vegetables in mixed cropping, traditionally irrigated by furrows diverting water from streams and springs flowing down the slopes of mount Kilimanjaro. These furrows polluted and partly contaminated by sewage, residuals of agricultural fertilizers and pesticides (used for coffee treatment) served also as source of drinking water supplies for the rural population.

Water borne diseases occurred frequently in the past and the population was threatened by long-term health hazards of the contaminants as a result of intensified agriculture and high population density. The supply of water in the lower areas including Hai township (Bomang'ombe), the administrative center of the district, mainly relied on the remaining highly polluted flows of the rivers and on saline ground water pumped from deep wells. They suffered severe scarcity of potable water especially during the dry season.

It is against this background that an initiative of the villagers supported by the Evangelical Lutheran Church of Tanzania Northern Diocese (ELCT-ND) approached donors and resulted in the commencement of the project activities in 1990 based on co-financing from the German government, the Tanzanian government and a remarkable physical contribution of beneficiaries (villagers) in self help.

2.1.2 General features of the focus group

A social economic study was conducted in the project area in November 1993 in which a total of 1,124 households i.e. 15.1% of the total population were interviewed. The results of the survey showed: the average size of a household to be 6.05 persons, 93% of all households depended on agriculture as their main source of income, and that the household's monthly average income was Tshs 18,830.00. The results also showed that 52.9% of the households disposed of more than Tshs 10,000.00 per month and only 20.6% disposed of less than Tshs 5,000.00 per month which was the average income per household in Tanzania according to the World Bank Publications in 1992 (Hai District Water Supply Project, February, 1994). The population in the project area can therefore be classified as being above the country's average income.

2.1.3 Water Distribution Network

The project is dependent on surface water sources of springs and rivers. The main criteria for selection of water sources were: safe yield, issues of water rights, raw water quality, topographic location and environmental impacts. Based on this criterion a system comprising Nkorowo Springs, Marire River, Mahewa River, Uroki and Saaki springs was chosen.

The water supply system is divided into two sections, which were implemented consecutively. Section one relies on the Saaki Springs tapping feeding the upper belt south villages of Shari, Mamba, and Uswaa the branch lines to Kyenge, Marire, Pombe shop Kishimbwe as well as K (Figure 1) through Kwasadala township. At Kwasadala this new system is connected to an existing reservoir of $100m^3$ capacity together with an existing distribution network supplying the population of the township.

Starting January 1990 to August 1993, section one of the project had been implemented in the form of a gravity system supplying inhabitants of Shari, Mamba, Uswaa, Roo and Kwasadala village (approximately 28,000 people) with adequate clean and safe drinking water mainly through public taps in the vicinity of their houses. Section two of the project includes the intake structures of Nkwarowo spring, Marire River, and Mehewa springs supplying the upper belt north and Uroki spring contributing to the supply of the lower belt.

The entire distribution network consists of about 22 km. of transmission main and 31 km of branch and distribution lines supplying the upper belt north and the lower belt down to Kambi ya Nyuki. Currently the area has a total of 182 public taps (PTs) and a total of 222 household (HH) connections. Water meters have been installed at all the public taps and house connections. The entire system is gravity fed making the average cost of water very low in international comparisons. The project target is to supply adequate, clean and hygienically safe water to a total of 90,000 inhabitants of the Hai district by the year 2010.

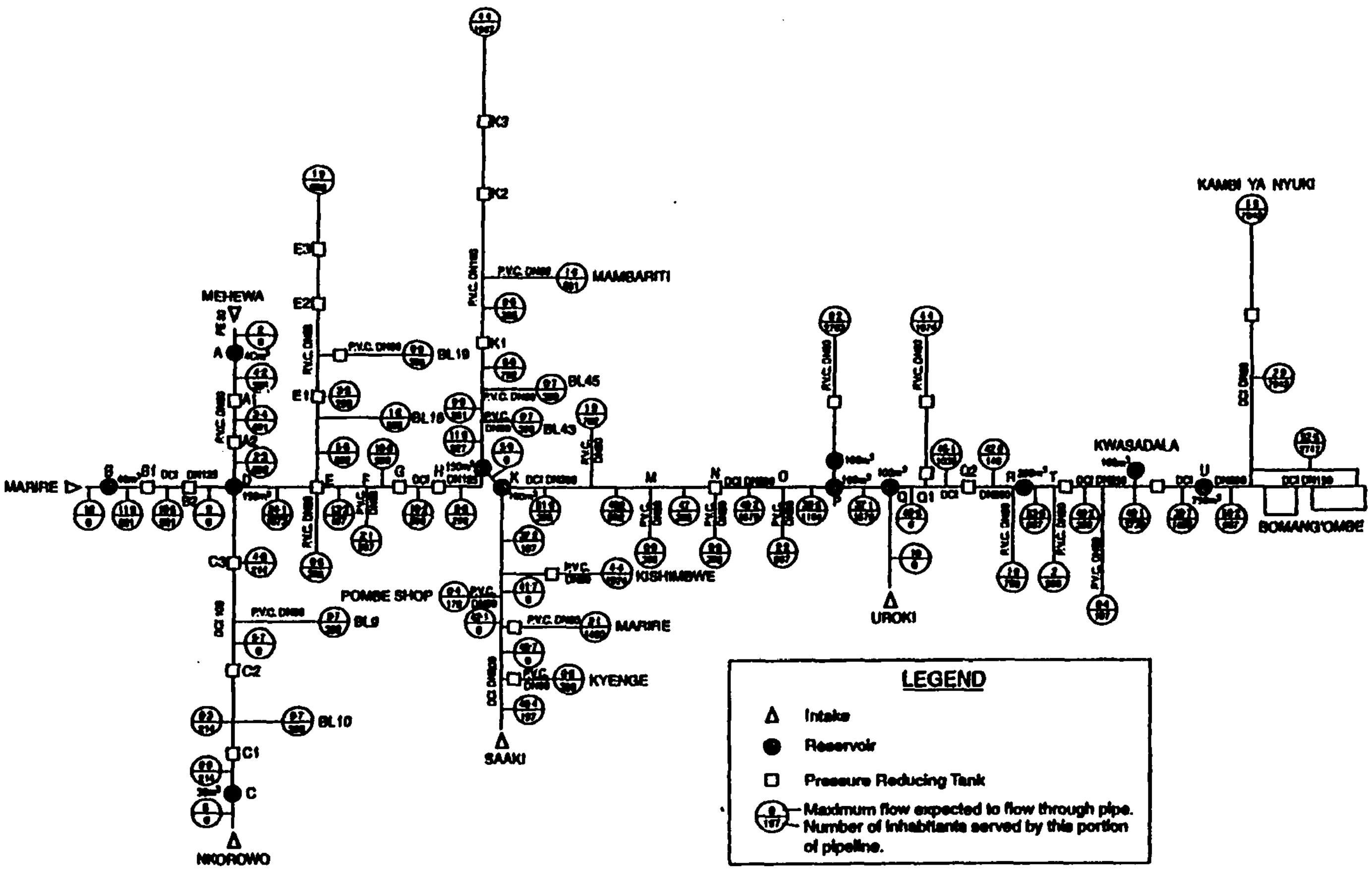

Figure 2.1: A Systematic Diagram of the Hai Water Supply System

2.1.4 Organizational Structure

The project is managed at the grassroots level on a two-tier organizational structure or system. At the lower tier is the Water User Committee (WUC) established in every town / village / user area, made up of not less than seven members of whom at least one half are women. Women are given prominence because the nature of their day to day activities gives them a particular appreciation of the importance of water for human survival and that they stand to be more directly affected by the project and do bear a greater burden when the facility is not available. The members of the committee are elected from the general assembly of the village council and function within the village government through its social welfare committee.

At the upper level is the Board of Water User Committee (BWUC), which is comprised of all villages (which are themselves legal entities) benefiting from the project and any other beneficiaries whether individuals or institutions. Together they form the HAI Water Supply Association (HAWASA) under the societies ordinance, as a Board of Water User Committee (Figure 2). The board has representations from: The water user committee, Hai District Engineer or his representative, the Regional Water Engineer or his representative and the Chief Officer of the ELCT-ND or his representative.

The board constitutes the principal planning and policy-making body for the entity. Ownership and management of the project is vested in the association. The central Government concerns itself with regulatory and controlling authority. Ownership is vested to the consumers. With the change in water policy from "free water for all" to Cost recovery, consumers are expected to bear the cost of rendering the service of supplying adequate, clean and safe water for the community.

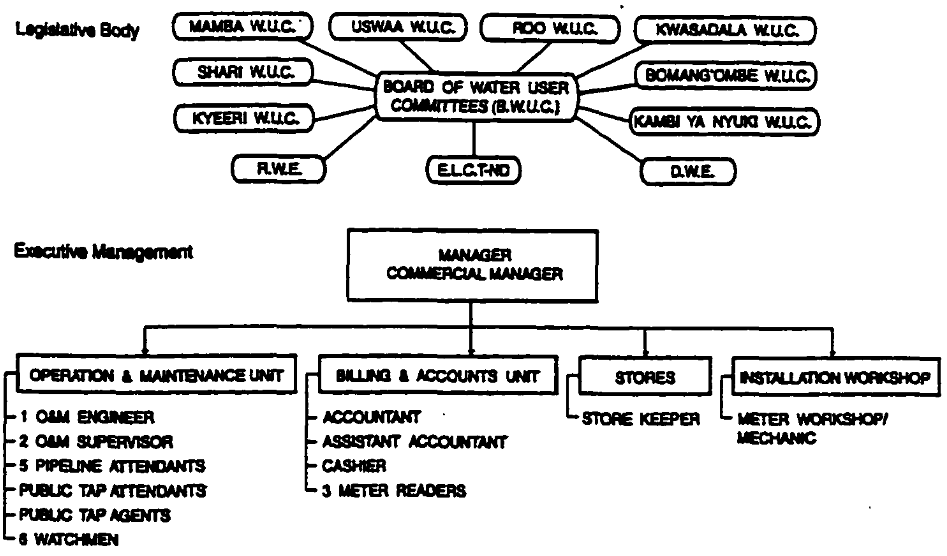

Figure 2.2: Organizational Setting, Hai Water Supply Association

2.1.5 Participation

It has been argued that participation of the beneficiaries of projects is a crucial ingredient in the well functioning, success and sustainability of a project. A study done in Tanzania by Kigingi (1984) revealed among other things that: villagers are willing to be trained as pump attendants or operators, and that beneficiaries are ready for cost sharing with the government (Mashauri and Katko, 1993).

In his study of Mtwara / Lindi project, Mtunzi (1984) found that people are willing to participate in the construction, repair and maintenance of their water schemes. He also observed that ownership of the water schemes by beneficiaries reduces vandalism of the projects (Mashauri and Katko, 1993).

In this project beneficiaries' participation in the form of self-help activities in the physical implementation of the project was quite substantial. In section one of the project an average of 65.7% of the households contributed physical labor in self-help mainly in excavation of trenches, 59.5% participated in the meetings to plan the project, 9.6% participated financially while 11.6% participated in kind. The total recorded number of self-help work during the construction of section one of the project alone amounted to 16,806 working days i.e. 134,448 working hours of self-help. The willingness to participate in section two was even higher with 90.9% of the households willing to contribute physical labor, and 55.8% willing to participate financially. Force account labor was employed to carry out work that required professional skills and experience in order to ensure good workmanship and satisfactory stable progress of work.

The participation of the beneficiaries in self-help for the implementation of the project has had some positive impacts on their acceptance of the project. Evidence from the positive attitude of the water users to maintain especially the public taps and to follow instructions for proper use, cleanliness and hygiene is given by the clean surroundings of the public taps, beautiful arrangements, planting of flowers, fencing and painting the tap structures.

A number of health and hygiene education campaigns, water user education campaigns, campaigns for the training of the public tap attendants were carried out by the project in cooperation with the Consultants team, the ELCT-ND and the village government.

2.2 Objectives

The objectives of this chapter are: to evaluate equity in water delivery in terms of the distribution of the public taps among different villages and townships in the project area; to compare both inter-temporal and intra-temporal billing collection efficiency between household and public tap consumption in the villages and townships, and between the townships and villages; to compare revenues from bills collected to the Operation and Maintenance (O&M) costs; and suggest ways to improve performance.

2.3 Methodology

The methodology that is followed in this paper in evaluating the managerial performance of the project in terms of equity in distribution, billing collection efficiency and cost recovery follows closely the recent works of Makombe and Sampath (1997), Sharma et al. (1991) and Sampath (1990).

2.3.1 Equity

Equity in water distribution is one of the desirable goals of any water supply system. In this chapter equity is defined as the achievement of a distribution of PT's among townships and villages in proportion to their number of households. Among the most frequently used measures of inequality in the distribution literature i.e. the range, the relative mean deviation, the information measure of inequality (Theil index), the variance and the coefficient of variation, Gini coefficient and the relative mean difference, only the Theil's information theoretic measure fulfills all the relevant equity axioms in addition to being additively decomposable (Sampath, 1990).

Theil's (1966) information theoretic measure is defined as:

$$I(x{:}y) = \sum x_i \ln(x_i / y_i) \quad (1)$$

where: x_i = the total number of public taps in the ith village/township as a proportion of the total number of PTs in the project area and y_i = the total number of equitable PTs in the ith village /township as a proportion of the total PTs in the project area.

Equity in this case will require y_i to be proportional to the number of households in each village/township. When there is perfect equity or equality in PTs distributions across villages/townships, $x_i \equiv y_i$ for all i resulting in the value of the index being zero. The higher the value of the index the higher the level of inequality in distribution.

The inequality measure can further be decomposed as follows:

$$I(x:y) = I_0(x:y) + \sum_{g=1}^{G} X_g I_g(x:y) \qquad (2)$$

where: $I_0(x:y)$ is the between system inequality (i.e. inequality between villages and townships in this context), and $I_g(x:y)$ is the inequality within villages and townships. X_g is the village/township's actual share of PTs and G = 2 (i.e. villages and townships).

Thus $I_0(x:y) = \sum_{g=1}^{G} X_g \ln(X_g/Y_g)$ and $I_g(x:y) = \sum_{i \in q} p_i \ln(p_i/n_i)$; where, $p_i = x_i/X_g$

$n_i =$ Thus $I_0(x:y) = \sum_{g=1} X_g \ln(X_g/Y_g)$ and $I_g(x:y) = \sum_{i \in q} p_i \ln(p_i/n_i)$; where, $p_i = x_i/X_g$

system inequality in PTs distribution and its decomposition into inequality between groups and within groups.

2.3.2 Billing Collection Performance

Billing collection performance can be measured by the deviation of actual collection (C) from the desired collection (C^*). This deviation called the performance error can be derived from the Theil's measure of accuracy of forecast defined as:

$$e_c^2 = 1/n\sum(C^* - C)^2 \tag{3}$$

Where: e_c^2 is the measure of the overall performance error in bill collection. This error could be further decomposed into measures indicating performance in terms of adequacy, equity or dependability and management capability as follows:

$$1/n\sum(C^* - C)^2 = (\bar{C}^* - \bar{C})^2 + (S_{c^*} - S_c)^2 + 2(1-r)*S_{c^*}*S_c \tag{4}$$

where $\bar{C}^*$ and $\bar{C}$ are means of the desired and actual bill collection respectively, S_{c^*}, S_c are the standard deviations and "r" is the correlation coefficient of C^* and C, and

$$r = (1/n\sum\ (C_i^* - \bar{C}^*)(C_i - \bar{C}))/(S_{c^*}*S_c) \tag{5}$$

The first term of the Right Hand Side (RHS) of equation (4), reflects error due to inadequacy (under-collection) in the monthly water bill collection. For a given total bill the difference in the mean of the actual from the desired collection indicates the level of inadequacy in the collection exercise. This error component is denoted by E_a.

The second term indicates error due to unequal variations in the monthly collections. The difference in the two standard deviations reflects a measure of dependability in bills collection. If the level of efficiency in bills collections is the same over time and over different amounts, one would expect the standard deviations to be the same. The higher the difference between them the lower the dependability of the system in collecting the bills. This error is denoted by E_e.

The third term is error due to incomplete covariance of scheduled and actual collection. It reflects management capability to implement scheduled water bill collection. If the water bills raised are collected in a timely manner the correlation coefficient between C^* and C will be unity making the term zero. A positive value of this term will indicate a lack of physical or management capability to collect the bills. This component of the error is denoted by E_m.

By dividing equation (4) by the total error term we get proportionate measures of adequacy, equity or dependability and management capability, and

$$E_a + E_e + E_m = 1 \qquad (6)$$

In this measure, a perfect performance occurs when the desired collection is achieved i.e. $C^* = C$. In such a case $e_c^2 = 0$.

2.4 Results and Discussion

Following the objectives of this chapter, the results of the analysis of equity in PTs distribution in the project area, bills collection efficiency and a comparison of revenue from bills collected to the O&M costs are summarized below.

2.4.1 Equity in Distribution

The current public taps and household connection distribution in the project area is shown in table 2.1. The number of persons per PT varies from 19 to 505 an equivalence of 3 to 86 households per PT respectively. If there would have been perfect equity, then the number of persons per PT or the number of households per PT would be identical across villages and townships, but that is not so. Villages and townships have

Table 2.1. Current public taps and household connection distribution in the project area

Village	No. of PTs	%	No. of HH Connections	%	* Population	Population with HH con.	Population using PTs	Indiniduals per PT	No. of Households	HH per PT	HH Interviewed
Kyeeri	32	18	19	9	6,575	115	6,460	202	1,087	34	164
Shari	46	25	39	18	9,817	236	9,581	208	1,623	35	244
Mamba	19	10	29	13	5,539	175	5,364	282	916	48	138
Uswaa	29	16	26	12	8,196	157	8,039	277	1,355	47	205
Roo	9	5	17	8	1,982	103	1,879	209	328	36	49
K' Sadala	5	3	14	6	2,612	85	2,527	505	432	86	65
B' Ng'ombe	35	19	78	35	10,178	472	9,706	277	1,682	48	254
Kware	7	4	0	0	135	0	135	19	22	3	2
Total	182	100	222	100	45,034	1,343	43,691		7,444		1,121

Note: * We assumed that the number of households interviewed in the socialeconomic study for the project area is proportional to the population of the cillages/townshiups and the household size of 6.05 given in the study.

74.2% and 25.8% of the existing PTs in the project area instead of their equitable share of 71.4% and 28.6% respectively. This is a deviation from perfect equality of only 2.8% indicating a fairly small inequality in distribution between villages and townships. While equitable distribution of the existing number of PTs in the Villages require to have 232 individuals per every PT, in reality the number of individuals per PT varies from 202 in Kyeri to 282 in Mamba village. In the townships on the other hand, equitable distribution of the existing PTs requires 263 individuals for each PT. The current distribution is such that the number of individuals per PT varies from 19 persons per PT in Kware Township to 505 persons in Kwasadala Township. Inequality within villages and within townships is therefore higher than that between villages and townships. This is also evident from the Theil index and its decomposition in table 2.2. The index shows that PTs within the

Table 2.2. Theil's index of inequality and its decomposition

	Inequality	%
Total	0.052775	100.00
Between group	0.002203	4.18
Within group	0.050571	95.82

project area are not equitably distributed but its low value of 0.052775 indicates a fairly good success in equitable distribution of PTs across the project area. The decomposition of this inequality measure between villages and townships revealed that 95.8% of the inequality is accounted for by within group inequalities while only 4.2% is due to between groups inequality. In other words whatever little inequality present in the project area, it is predominantly because of lack of equitable distribution within villages and within townships than between villages and townships. Household connections are provided according to the ability of the household to meet the costs of connection and meter reading estimated to be Tsh. 450,000.00 in 1992.

Although the survey conducted in the area showed an average of only 8.5% of the households in each village/township could afford household connections, the actual number of connections in each village/township is on average 1.9 times more than what was indicated by the survey results. Whether the current connections are equitable i.e. proportional to the demand in each village/township is not clear given the information at hand.

2.4.2 Bills Collection Performance

Villages: Table 2.3 and 2.4 shows the village monthly public taps and household water consumption, billings, collection rates and the price/m^3 of water sold for the period 1995 and 1996 respectively. Village PT water is priced at Tsh. 50.00 per m^3 and Tsh. 150.00 per m^3 for household connections according to project documents and reports. However, the tables reveal that for the months of January to March, May and June 1995, the PT price per m^3 varied from Tsh 9.00 in June to Tsh 63.00 in May 1995 then stabilized at the set price thereafter. On average the PT water was priced at 42.02 Tsh. per m^3 (i.e. 4.04%) of the set price. For the household connections the problem is even worse.

Table 2.3. *Village monthly public tap and household water consumption (m^3), billing (Tsh) and monthly collection rates for 1995*

	Public tap consumption					Household consumption				
Month	Qty	Total bill	Price per m3	Collected	% Collected	Qty	Total Bill	Price per m3	Total Collected	% Collected
Jan. 95	8,566.00	147,082.00	17.17	88,773.00	60.36	255.00	60,982.00	239.15	60,982.00	100.00
Feb. 95	7,341.00	210,576.00	28.68	128,485.00	61.02	293.00	14,647.00	49.99	14,647.00	100.00
Mar. 95	6,817.00	236,791.00	34.74	143,335.00	60.53	237.00	8,765.00	36.98	8,765.00	100.00
Apr. 95	6,082.00	307,242.00	50.52	186,263.00	60.62	234.00	8,285.00	35.41	8,285.00	100.00
May. 95	4,896.00	312,770.00	63.88	189,924.00	60.72	236.00	6,317.00	26.77	6,317.00	100.00
Jun. 95	7,045.00	63,435.00	9.00	38,341.00	60.44	283.00	9,881.00	34.92	9,881.00	100.00
Jul. 95	8,748.00	439,789.00	50.27	263,490.00	59.91	311.00	8,858.00	28.48	8,858.00	100.00
Aug. 95	8,854.00	442,719.00	50.00	276,851.00	62.53	271.00	27,151.00	100.19	27,151.00	100.00
Sep. 95	8,987.00	449,395.00	50.01	292,753.00	65.14	359.00	35,838.00	99.83	35,838.00	100.00
Oct. 95	10,559.00	527,963.00	50.00	352,681.00	66.80	379.00	37,984.00	100.22	37,984.00	100.00
Nov. 95	9,247.00	462,370.00	50.00	310,098.00	67.07	451.00	45,276.00	100.39	45,276.00	100.00
Dec. 95	10,706.00	535,311.00	50.00	362,893.00	67.79	713.00	71,242.00	99.92	71,242.00	100.00
Total	97,848.00	4,135,443.00		2,633,887.00	63.69	4,022.00	335,226.00		335,226.00	100.00
Average			42.02					79.35		

Source: Bomang'ombe Water Supply Trust (1996), Group consumer data for 1995.

Table 2.4. Village monthly public tap and household water consumption (m^3) billing (Tsh) and monthly collection rated for 1996

	Public tap consumption					Household consumption				
Month	Qty	Total bill	Price per m^3	Collected	% Collected	Qty	Total Bill	Price per m^3	Total Collected	% Collected
Jan. 96	10,444.00	522,221.00	50.00	190,070.00	36.40	580.00	87,046.00	150.08	26,670.00	30.64
Feb. 96	8,134.00	406,693.00	50.00	346,339.00	85.16	782.00	117,343.00	150.05	10,000.00	8.52
Mar. 96	9,654.00	482,722.00	50.00	168,614.00	34.93	1,654.00	248,112.00	150.01	81,848.00	32.99
Apr. 96	6,458.00	322,911.00	50.00	41,800.00	12.94	1,240.00	185,930.00	149.94	35,243.00	18.95
May. 96	6,740.00	337,001.00	50.00	196,167.00	58.21	1,129.00	169,393.00	150.04	114,792.00	67.77
Jun. 96	8,225.00	411,233.00	50.00	165,663.00	40.28	1,097.00	164,573.00	150.02	111,567.00	67.79
Jul. 96	7,137.00	356,858.00	50.00	425,588.00	119.26	1,335.00	200,273.00	150.02	113,041.00	56.44
Aug. 96	7,142.00	357,115.00	50.00	225,554.00	63.16	1,489.00	223,373.00	150.02	190,900.00	85.46
Sep. 96	6,721.00	336,045.00	50.00	172,596.00	51.36	1,335.00	200,237.00	149.99	275,442.00	137.56
Oct. 96	7,662.00	383,117.00	50.00	222,941.00	58.19	1,678.00	251,697.00	150.00	184,926.00	73.47
Total	78,317.00	3,915,916.00		2,155,332.00	55.04	12,319.00	1,847,977.00		1,144,429.00	61.93
Average			50.00					150.02		

Source: Bomang'ombe Water Supply Trust (1996), Group consumer data for 1996.

With the exception of January when the price is shown to be 1.6 times what it should be, probably reflecting collection of past dues, water prices are shown to vary from Tsh 26.77 to Tsh $100/m^3$. On average the price charged in 1995 was Tsh 79.35 per m^3 i.e. 52.9% of what the price should be. The 100% collection rate shown is therefore effectively 52.9 % of what should have been collected if billing was done correctly. The situation improved from January 1996 when the price charged equaled the set price.

Townships: Tables 2.5 and 2.6 show the monthly water consumption in m^3, monthly total billings, collection rates and per unit price of water sold for public taps and household connections in the townships for 1995 and 1996. The price of PT water is set at Tsh 150.00 per m^3 and Tsh 250.00 for household connected water. Between January and September 1995 PT prices varied from Tsh 9.01 in June to Tsh 91.31 per m^3 in September before stabilizing at the set price from October onwards. On average however, water was sold at Tsh 69.15 per m^3 i.e. only 46.1% of the set price. The collection rate average of 83.17 % therefore would have been less than half if the full bill was considered. Household collections had the same problem from January to July, 1995 with the price being only 20% of the set price. Between August and December 1995 the price improved to reach 60% of the set price. On average the price charged was Tsh 94.75 per m^3 (only 37.9% of the set price). Starting January 1996, the full price was achieved.

Table 2.7 shows the collection rates per village / township for 1995 and 1996. With exception of Shari and Mamba villages, which had collection rates of less than 50% in 1995 the rest of the villages and townships, average collection was 90.8%. In 1996

Table 2.5. Townships monthly Public tap and household water consumption (m^3), billing (Tshs) and monthly collection rates for 1995.

	Public tap consumption					Household consumption				
Month	Qty	Total bill	Price per m^3	Total collected	% Collected	Qty	Total bill	Price per m^3	Total collected	% Collected
Jan. 95	580.00	9,961.00	17.17	6,275.00	63.00	1,023.00	51,161.00	50.01	51,161.00	100.00
Feb. 95	591.00	16,958.00	28.69	10,344.00	61.00	956.00	47,788.00	49.99	47,788.00	100.00
Mar. 95	629.00	21,854.00	34.74	13,549.00	62.00	760.00	38,000.00	50.00	38,000.00	100.00
Apr. 95	462.00	23,327.00	50.49	14,696.00	63.00	499.00	24,951.00	50.00	24,951.00	100.00
May. 95	348.00	22,233.00	63.89	13,896.00	62.50	365.00	18,258.00	50.02	18,258.00	100.00
Jun. 95	470.00	4,236.00	9.01	2,711.00	64.00	405.00	20,241.00	49.98	20,241.00	100.00
Jul. 95	671.00	36,289.00	54.08	24,947.00	68.75	522.00	26,085.00	49.97	26,085.00	100.00
Aug. 95	5,066.00	153,720.00	30.34	111,827.00	72.75	566.00	84,997.00	150.17	84,997.00	100.00
Sep. 95	3,036.00	277,203.00	91.31	215,530.00	77.75	702.00	105,321.00	150.03	105,321.00	100.00
Oct. 95	1,379.00	206,866.00	150.01	179,237.00	86.64	1,374.00	206,103.00	150.00	206,103.00	100.00
Nov. 95	1,463.00	219,495.00	150.03	188,965.00	86.09	259.00	48,394.00	186.85	48,394.00	100.00
Dec. 95	3,616.00	542,337.00	149.98	494,273.00	91.14	857.00	128,518.00	149.96	128,518.00	100.00
Total	18,311.00	1,534,479.00		1,276,250.00	83.17	8,288.00	799,817.00		799,817.00	100.00
Average			69.15					94.75		

Source: Bomang'ombe Water Supply Trust (1996), Group consumer data for 1995

Table 2.6. Townships' monthly public tap and household water consumption (m^3), billing (Tsh) and monthly collection rates for 1996

	Public tap consumption					Household consumption				
Month	Qty	Total bill	Price per m^3	Total collected	% Collected	Qty	Total bill	Price per m^3	Total collected	% Collected
Jan. 96	4,248.00	637,214.00	150.00	637,214.00	100.00	694.00	173,388.00	249.84	126,891.00	73.18
Feb. 96	4,515.00	677,255.00	150.00	671,640.00	99.17	639.00	159,784.00	250.05	84,906.00	53.14
Mar. 96	6,985.00	1,047,754.00	150.00	685,674.00	65.44	568.00	142,089.00	250.16	125,078.00	88.03
Apr. 96	3,652.00	547,815.00	150.00	753,601.00	137.56	1,083.00	270,859.00	250.10	256,614.00	94.74
May. 96	2,566.00	384,961.00	150.02	453,690.00	117.85	869.00	217,129.00	249.86	191,561.00	88.22
Jun. 96	4,882.00	732,262.00	149.99	249,442.00	34.06	961.00	240,272.00	250.02	132,576.00	55.18
Jul. 96	5,352.00	802,848.00	150.01	744,679.00	92.75	1,498.00	374,382.00	249.92	243,187.00	64.96
Aug. 96	6,270.00	940,493.00	150.00	715,902.00	76.12	2,122.00	530,493.00	250.00	303,310.00	57.18
Sep. 96	7,104.00	1,065,526.00	149.99	816,154.00	76.60	2,301.00	575,279.00	250.01	393,754.00	68.45
Oct. 96	7,482.00	1,122,335.00	150.00	1,055,538.00	94.05	2,403.00	600,712.00	249.98	519,055.00	86.41
Total	53,056.00	7,958,463.00		6,783,534.00	85.24	13,138.00	3,284,387.00		2,376,932.00	72.37
Average			150.00					249.99		

Source: Bomang'ombe Water Supply Trust (1996), Group consumer data for 1996.

Table 2.7. Collection rates per Village / Townshis.

	1995				1996			
Village	Amount due	Amount paid	Balance due	% paid	Amount due	Amount paid	Balance due	% paid
Kyeeri	197,516.00	197,516.00	0.00	100.00	424,123.00	357,446.00	66,677.00	84.28
Shari	1,305,245.00	616,491.00	688,754.00	47.20	1,082,789.00	681,807.00	400,982.00	62.97
Mamba	808,918.00	307,980.00	500,938.00	38.10	476,435.00	212,547.00	263,888.00	44.61
Uswaa	1,192,135.00	910,050.00	282,085.00	76.30	766,972.00	423,204.00	343,768.00	55.18
Roo	695,992.00	444,826.00	251,166.00	63.90	428,246.00	320,613.00	107,633.00	74.87
K'sadala	692,234.00	692,234.00	0.00	100.00	606,114.00	606,114.00	0.00	100.00
B'ng'ombe	836,115.00	836,115.00	0.00	100.00	5,414,705.00	5,091,388.00	323,317.00	94.03
Hydrants	3,853,551.00	3,853,551.00	0.00	100.00	2,553,829.00	2,553,829.00	0.00	100.00
Private HC	653,701.00	624,522.00	29,179.00	95.50	3,133,502.00	2,868,997.00	264,505.00	91.56
TOTAL	10,235,407.00	8,483,285.00	1,752,122.00	82.90	14,886,715.00	13,115,945.00	1,770,770.00	88.11
AVG[a]				90.81	AVG[b]			82.86

Notes: Average Collection rate 85.493394

[a] without Shari and Mamba villages.

[b] without Mamba village.

Source: Project Reports.

collection rates improved with only one village with a collection rate of less than 50% (i.e. 44.6%). The overall collection rate increased from 82.9% (1995) to 88.1% (1996).

The project overall average collection rate for the two years was 85.49% which is a fairly good performance compared to the collection rate of only 60% for Morogoro town for the period 1982 - 1989 (Mashauri and Katko, 1993).

2.4.3 Performance Error Analysis

The results of the performance error analysis are summarized in tables 2.8 and 2.9. Table 2.8 presents the absolute error in the system additively decomposed to the various components of the system to show the contribution of each component to the absolute error (additive decomposable analysis) and table 2.9 summarizes the results of the individual component analysis.

From table 2.8, it can be seen that villages accounts for 52.87% of the total absolute error committed in the entire project while townships accounts for 47.13% of the error. Both villages and townships performance deteriorated over time. Townships performance deteriorated more than that of villages.

A comparison between public taps and household performance show that public taps accounted for 84.61% of the total error as compared to 15.39% by the households. Under the public taps, villages have a higher absolute error (46.54%) as compared to townships (38.07%), and a lower absolute error (6.33%) as compared to townships (9.06%) under the household connections. Over time, the absolute error increased 5.3 times in 1996 compared to 1995. While the error due to villages increased 2.48 times,

Table 2.8. Analysis of Performance error decomposition

	% of total absolute error		% of total absolute error
Total error:		Overall:	
Villages	52.87	1995	15.88
Townships	47.13	1996	84.12
Total error	100.00		100.00
Villages:		1995	
1995	15.18	Villages	15.18
1996	37.69	Townships	0.7
Total	52.87	Total	15.88
Townships		Villages:	
1995	0.70	PTs	15.18
1996	46.43	HH	0.00
Total	47.13	Total	15.18
		Townships:	
PTS	84.61	PTs	0.70
HH	15.39	HH	0.00
Total	100.00	Total	0.70
PTS:		1996	
Villages	46.54	Villages	37.69
Townships	38.07	Townships	46.43
Total	84.61	Total	84.12
HH:		Villages:	
Villages	6.33	PTs	31.36
Townships	9.06	HH	6.33
Total	15.39	Total	37.69
		Townships:	
		PTs	37.37
		HH	9.06
		Total	46.43

that due to townships increased 6.33 times between the two periods indicating a higher absolute contribution to total error by villages. Both village public taps and household performance deteriorated over time. Similarly, townships' public taps and household also deteriorated over time.

2.4.4 Sub-system Analysis

The results of the sub-system performance error analysis are given in table 2.9 in terms of adequacy (under-collection) error E_a, collection dependability or instability error E_e, management capability error E_m, the total error committed e_c^2 and the maximum possible error that could be committed if nothing was collected ($Max.e_c^2$). The maximum possible error is higher than e_c^2 if the actual bill collection is less than the total bill and it is equal to e_c^2 when nothing has been collected. The table also apportions the total error among its three components and expresses the total error as a proportion of the maximum possible error. The lower the proportion the better is the performance.

From the table, the total committed error for the entire project is 11.29% of the maximum possible error. This shows a fairly good success in collecting water bills. Management inability to collect water bills in a timely manner (E_m), "under collection" of the monthly bills (E_a) and lack of dependability or instability in the monthly collections (E_e) accounts for 56.8%, 47.5% and 11.5% of the total error committed respectively.

The total error is dis-aggregated into error components due to villages and townships, and error components due to public taps and household connections. Overall, townships performed better than the villages. While both under-collection of bills and bills collection instability errors are higher for the villages than for the townships, management capability error is higher in the townships than in the villages.

Table 2.9. Performance error analysis.

	E_a	E_e	E_m	e^2_c	$Max\ e^2$ $(e^2_c/Max\ e^2_c)$		E_a	E_e	E_m	e^2_c	$Max\ e^2$ $(e^2_c/Max\ e^2_c)$
Project (Overall)	0.3176	0.1147	0.5677	1.0000	0.1129	Townships	0.2788	0.3786	0.3425	1.0000	0.0173
Villages	0.4751	[illegible]	[illegible]	1.0000	0.2065	PT	0.5576	0.2966	0.1458	1.0000	0.0204
Townships	0.1856	[illegible]	[illegible]	1.0000	0.0761	HH	0.0000	0.0000	0.0000	0.0000	0.0000
PT Overall	0.4162	0.0341	0.5498	1.0000	0.1134	1996					
Villages	0.7305	0.0121	0.2574	1.0000	0.2030	Overall	0.4317	0.0080	0.5603	1.0000	0.2558
Townnships	0.1723	0.1132	0.7145	1.0000	0.0736	Villages	0.5661	0.0082	0.4257	1.0000	0.2765
HH Overall	0.2693	0.2585	0.4723	1.0000	0.1192	PT	0.6947	0.0306	0.2748	1.0000	0.2837
Villages	0.2497	0.0640	0.6863	1.0000	0.2361	HH	0.5494	0.0932	0.3574	1.0000	0.2457
Townships	0.2903	0.4162	0.2935	1.0000	0.0886	Townships	0.3281	0.0298	0.6421	1.0000	0.3489
1995						PT	0.2596	0.0165	0.7240	1.0000	0.0774
Overall	0.2855	0.5211	0.1934	1.0000	0.1796	HH	0.6386	0.1219	0.2396	1.0000	0.0943
Villages	0.4349	0.5435	0.0215	1.0000	0.1268						
PT	0.8699	0.1224	[illegible]	[illegible]	0.1279						
HH	0.0000	0.0000	[illegible]	[illegible]	0.0000						

Both public taps and household connections performed fairly well when we compare the actual error committed to the maximum possible error. Although the PTs accounts for a higher percentage of the absolute error committed (84.61%), in terms of the maximum error that could have been committed PTs performed better than the households. Under-collection of bills and management capability errors are higher for the PTs than for the HH while bills collection rates are more stable for the PTs than for the households.

Village public taps' under-collection error accounts for 73.1% of the total error while in the townships management capability error accounted for 71.45%. Error due to collection instability is higher in the townships (11.32%) as compared to 1.21% in the villages. For the household connection group, townships performed relatively better than villages despite the fact that townships has a higher percentage error committed compared to that of in the villages. While management capability seems to be a major problem in the villages, collection instability is a major problem in the townships.

The project performance deteriorated between 1995 and 1996. Overall, all error components namely adequacy, instability and management capability are higher in 1996 than in 1995. Both villages' and townships' overall performance, public taps and household connection performance deteriorated over time. While townships performed better than the villages in 1995, the trend was reversed in 1996.

2.4.5 Performance in Cost Recovery

The households expressed willingness to pay according to metered consumption is summarized in table 2.10. The table shows an average of 61.9% of the households were willing to pay according to metered consumption and the average willingness to pay was Tsh 970.00 per month (about 4.9% of the households expenditure per month). With an assumed consumption rate of 20 liters per capita day from public taps and a household size of 6.05 persons, the consumption rate is equivalent to 3.63m^3 per household per month. If this amount is billed at the rate of Tsh. 255.00 per m^3, which includes all costs and a 5% return on investment, the monthly bill will amount to Tsh. 926.00, which is below the stated willingness to pay of Tsh. 970.00

Table 2.10. Households' WTP according to meter readings and per month

Village	Yes(%)	No (%)	Tsh/month
Kyeri	71.30	28.10	1,309.00
Shari	54.90	44.60	1,361.00
Mamba	34.80	65.20	420.00
Uswaa	47.30	47.30	830.00
Roo	55.10	44.90	441.00
K'Sadala	58.50	41.50	1,230.00
B'Ng'ombe	73.20	25.60	1,204.00
K'Nyuki	100.00		
Average	61.89	42.46	970.71

Source: Hai District Water Supply Project, Feasibility Study main text (World Bank, 1994)

The billing procedure used by BWUC is defined to cover the Operations and Maintenance (O&M) costs of the supply system. Table 2.11 shows the O&M costs and income collected from water users for the period September 1993 to May 1995. With the exception of September to December 1993 period, where collections covered only 57.45% of the O&M costs, the collections from January 1994 to May 1995 covered on average 127.39% of the O&M costs. This is quite a remarkable performance compared to the study of Morogoro town for the period 1984 to 1989 in which only twice did the amount collected exceed 50% of the direct O&M cost.

Table 2.11. Settlement of Operations and Maintanance Costs September 1993 - May, 1995

	Cost of O&M (Ths)		Income from billing Collected by BWUA		Balance	% Cost
Month	Monthly	Cummulative	Monthly	Cummulative	Cummulative.	coverage
Sep. 93-Dec. 93	694,800.00	694,800.00	399,194.00	399,194.00	(295,606.00)	57.45
Jan-94	186,000.00	880,800.00	686,875.00	1,086,069.00	205,269.00	123.30
Feb-94	236,428.00	1,117,228.00	386,763.00	1,472,832.00	355,604.00	131.83
Mar-94	291,150.00	1,408,378.00	247,730.00	1,720,562.00	312,184.00	122.17
Apr-94	246,080.00	1,654,458.00	189,238.00	1,909,800.00	255,342.00	115.43
May-94	256,260.00	1,910,718.00	134,397.00	2,044,197.00	133,479.00	106.99
Jun-94	213,300.00	2,124,018.00	283,415.00	2,327,612.00	203,594.00	109.59
Jul-94	208,380.00	2,332,398.00	513,261.00	2,840,873.00	508,475.00	121.80
Aug-94	369,920.00	2,702,318.00	147,852.00	2,988,725.00	286,407.00	110.60
Sep-94	315,261.00	3,017,579.00	286,432.00	3,275,157.00	257,578.00	108.54
Oct-94	217,460.00	3,235,039.00	207,658.00	3,482,815.00	247,776.00	107.66
Nov-94	136,920.00	3,371,959.00	123,004.00	3,605,819.00	233,860.00	106.94
Dec-94	350,510.00	3,722,469.00	664,490.00	4,270,309.00	547,840.00	114.72
Jan-95	238,520.00	3,960,989.00	588,778.00	4,859,087.00	898,098.00	122.67
Feb-95	267,108.00	4,228,097.00	610,779.00	5,469,866.00	1,241,769.00	129.37
Mar-95	215,572.00	4,443,669.00	149,576.00	5,619,442.00	1,175,773.00	126.46
Apr-95	253,158.00	4,696,827.00	345,099.00	5,964,541.00	1,267,714.00	126.99
May-95	139,842.00	4,836,669.00	196,984.00	6,161,525.00	1,324,856.00	127.39
Total		4,836,669.00		6,161,525.00		127.39

Source: Hai - District Water Supply Project. Board of Water User Committee Quarterly Reports.

CHAPTER 3

PERFORMANCE EVALUATION OF WATER SUPPLY IN TANZANIA THE CASE OF DAR ES SALAAM CITY

3.1 Introduction

The provision of adequate supplies of potable water for use in the urban areas in the developing countries for drinking, cooking, cleaning and bathing is crucial for the well being of the people. The demand for such supplies in the third world has been increasing over time as a result of the raising standards of living that occur with economic development, the population increase resulting from natural growth as well as rural-urban migration and rising per-capita income.

Adequate potable water supplies also improves health by reducing the incidence of water related illnesses such as diarrhea, cholera etc. which are rampant in many developing countries. By doing so it also helps to reduce both the mortality and morbidity rates and the number of workdays lost. The reduction of the number of workdays lost on the other hand could increase the gross domestic product substantially but unfortunately labor statistics are not available to estimate this impact. Also, in most developing countries characterized by chronic balance of payments (BOP) problems, with medicine mostly being an imported item, reducing the incidence of illnesses will help reduce the demand for such medicines and thereby easing the BOP problems facing the developing country in question. Under such circumstances planning for an efficient and equitable water delivery systems both in the short-run and long-run is critical to ensure that the population gets adequate water supplies.

Despite its importance, equity and efficiency in urban water supplies in the developing countries is a topic that has neither received sufficient coverage in the economic literature nor has it been dealt with adequately in any practical objective performance evaluation of actual projects. In any urban setting, population size differs from one area to another and so should water supply distribution. It is therefore important to assess how the available water is distributed among these different areas in relation to their population (equity) and improvements that can be made. What may be perceived as a water shortage problem in a given city may end up being a water distribution problem that can be corrected with a minimum of investments. In the developing countries where investible resources are scarce the importance of this issue cannot be understated. Such considerations need to be incorporated in both the short and long term planning by cities and water authorities. Efficiency in such a distribution system is also crucial. By efficiency we mean the ability of a water authority to reach a given supply target. A negative deviation from such a target will reflect a measure of inefficiency in the system. Such a measure will serve as a signal to the water authority to look for better ways to reach their supply targets and allow comparison of performances across different geographic areas to determine where to concentrate limited available resources and efforts so as to improve performance.

3.1.1 The city: Location Population and Climate

Dar Es Salaam (DSM) is the largest city in Tanzania. It is the political, economic and cultural center of the country. The city has an area of 1,393 km^2. It is located on the Eastern Coast of Africa at latitudes 6° 45′ S and longitudes 39° 18′ E. The population and the rate of urbanization have increased rapidly over the years. The population as per the 1988 census stood at 1, 360,850 people. The estimated population for 1995 was 1,961,002 people. The city is divided into three administrative districts namely: Kinondoni, Ilala and Temeke. Each of the districts is further divided into wards.

The temperature in the city is usually high ranging from 17° centigrade to 32° centigrade with humidity of between 50% and 90%. The main winds are the monsoons blowing to and from the Indian Ocean. Most of the rain falls between March and May, but continued showers throughout the year are common. Total rainfall per year is between 1,000 and 1,400 mm.

3.1.2 Sources of Water Supply

The main source of water supply for the city of Dar Es Salaam is Ruvu River flowing north on the West Side of the city towards the Indian Ocean. The supply is supplemented to a small extent by taping water from river Kiziga at Mtoni. Water is taken from two different intakes located 20 kms apart on Ruvu River. The older is the Upper Ruvu System located 65km, west of the city along Morogoro road, while the second intake is the Lower Ruvu System located near Bagamoyo town, down stream from the Upper Ruvu System and about 18km upstream from the mouth of the river. The total installed water supply capacity is 270,800 m^3/day (59.5 mgd) i.e.1.57 times the estimated total demand for the year 2000 and 1.1 the total estimated demand for the year 2015.[1] However two thirds of the water delivered by the Upper Ruvu system and between 10% and 20% of that delivered by the Lower Ruvu system are consumed or lost by leakage along the transmission mains before reaching the reservoirs in the city. As a result water available to the city at present is approximately 181,000m^3/day i.e. two thirds of the design capacity (JICA, 1991). Water losses in the distribution system (involving house service pipes, valve seatings and public standposts) have been estimated to range between 25% and 40% of the flow into the system further reducing the water available to the city to between 108,600 m^3/day and 135,750m^3/day. This supply is equivalent to between 0.63 and 0.79 of the total estimated demand for the year 2000 and between 0.44 and 0.55 that for the year 2015. The water supply in the city for the last few years has been very poor not only in terms of the per capita availability but also long hours and days of no supply. The city is faced with a serious water supply crisis that has greatly affected the amount of water available for household use. Currently residents are forced to supplement their water requirements by resorting to locally dug wells or buying from private water vendors who fetch their water from distant places on bicycles or hand drawn carts (Michael, 1999).

3.1.3 Water Supply System

The Dar es Salaam Water and Sewerage Authority (DAWASA), a public authority responsible for water supply and sewerage services, manage water supply for most of the densely populated areas of Dar es Salaam. The distribution network is

[1] Demand as estimated by the Rehabilitation Study of Dar es Salaam Water Supply System 1995. Total

supplied from reservoirs at the University of Dar Es Salaam, Kimara and Mtoni. The service area in Dar es Salaam encompasses $321km^2$ extending 25km from north to south and 15 km from east to west. In the northern region, along Bagamoyo road, transmission mains convey water treated at the lower Ruvu water treatment plant to the University reservoir while in the western region, along Morogoro road, transmission mains convey water treated at the Upper Ruvu water treatment plant to the Kimara reservoir. In the southern region a small amount of water is treated at the Mtoni treatment plant and pumped to the distribution network (Figure 3.1). Pipelines tapped from these two transmissions serve some wards in the southern and western regions, in part. Apart from these, outlying wards in the northern, western and southern regions are also served by a system of shallow wells under the administration of the Dar Es Salaam Rural Water Supply Department (RWSD). The current water treatment is far from being satisfactory. The system has no systematic and routine water quality monitoring. Cleaning of the mains and swabbing is not being done on any regular basis. Also residual chlorination is not found in water supplied in some areas. The quality of water supplied to consumers through the distribution system is aesthetically unsatisfactory and occasionally bacteriologically unsafe (JICA 1991).

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demand = Domestic + Non-domestic demands (i.e. industrial, institutional and commercial demands)

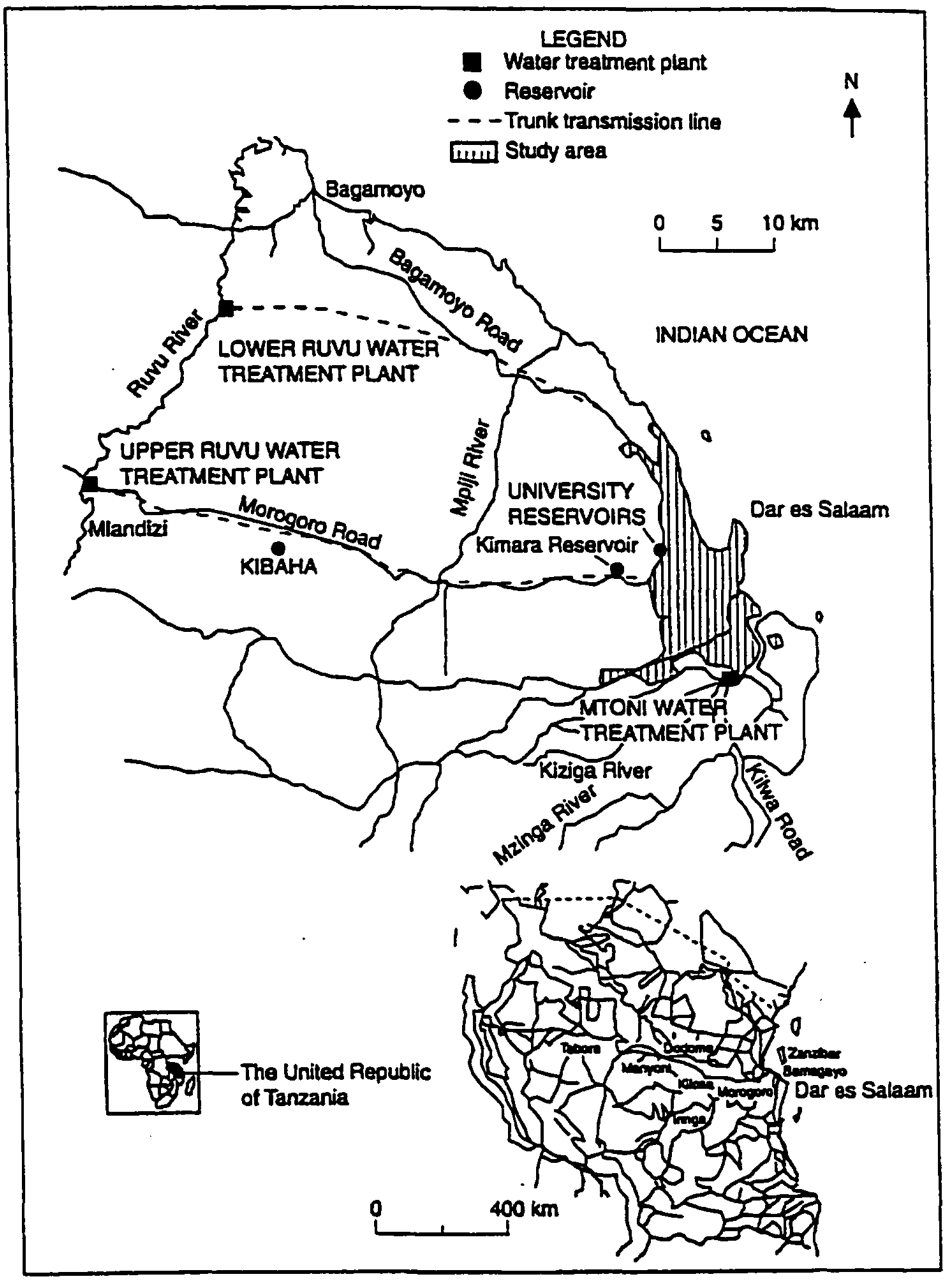

Figure 3.1: Location and the Water Supply System for the city of Dar Es Salaam (JICA, 1991)

DAWASA is administratively divided into five areas or branches located in the three administrative districts of the city. Kinondoni district has three branches namely Kinondoni, Kawe and Magomeni. The remaining two districts have one branch each i.e. Ilala branch (Ilala district) and Temeke branch (Temeke district). Each branch covers a number of wards and for Kinondoni district with more than one branch wards form the branches and branches form the district. This chapter will focus on the distribution system under DAWASA. It will analyze the current and recent past level of water supply in different districts, DAWASA branches and wards. Equity in distribution will also be addressed. These analyses are done in terms of performance between and within the districts and the five administrative branches under DAWASA for the years 1996,1997 and 1998. Recommendations to improve equity in distribution and managerial performance efficiency are given.

3.2 Data

Data used in the analysis come from two main sources. The Rehabilitation Study of Dar Es Salaam Water Supply System 1995 provide population data for wards, districts and branches as per the 1978 national population census. The census figures are used to project population for the years 1996, 1997 and 1998. Monthly estimated water supply figures were obtained from DAWASA records for the same three years through a survey done by the authors in July 1998. A total of 19 months of data is used. Daily water supply was calculated by dividing the monthly total by the number of days in the month. For the year, daily water supply was obtained by dividing the annual total water supply by the actual number of days in the months for which data was available. In 1996 data was available for 4 months (123 days). For years 1997 and 1998 data was available for 10 months (334 days) and 5 months (151 days) respectively.

3.3 Objectives

The objective of this chapter is to evaluate equity and efficiency aspects of urban water supplies in the city of Dar Es Salaam in terms of the amount of water supplied to different districts and DAWASA branches and suggest ways to improve the situation.

3.4 Methodology

The methodology that is followed in this paper in evaluating planning performance in terms of water delivery efficiency and equity in distribution closely follows the recent works by Reweta and Sampath (1997), Makombe and Sampath (1997), Sharma et al. (1991), and Sampath (1990).

The analysis is done in two parts. In the first part equity is analyzed at the entire city level using data from 26 wards in the city, to see how the available water is distributed within the city. The second part deals with efficiency in water supply in the city by comparing actual supplies to the equitable amount of water that should be supplied to different wards given their populations and the water available to the city. In this part the interest is in the positive deviations from the quantity required as just defined. As such wards that achieve or surpass this equitable requirement are removed from this analysis. This part of the analysis will therefore have less total number of wards than the equity analysis.

3.4.1 Equity

Equity in water distribution is one of the desirable goals of any water supply system. In this chapter equity is defined as the achievement of a water supply among districts, branches, and wards that is in proportion to their population. Among the most frequently used measures of inequality in the distribution literature i.e. the range, the relative mean deviation, the information measure of inequality (Theil index), the variance and the coefficient of variation, Gini coefficient and the relative mean difference, only the Theil's information theoretic measure fulfills all the relevant equity axioms such as scale independence, equal additions, principle of population, weak and strong principles of transfers and symmetry in addition to being additively decomposable (Sampath, 1990).

Theil's (1966) information theoretic measure is defined as:

$$I(x:y) = \sum x_i \ln(x_i / y_i) \qquad (1)$$

Where: x_i = a unit's actual quantity of an attribute as a fraction of the system's actual total quantity of the attribute and y_i = the expected share or the required distribution of the attribute.

Equity in this case will require y_i to be proportional to the population in each district or DAWASA branch. When there is perfect equality in water supply distribution across these entities $x_i \equiv y_i$ for all "i" resulting in the value of the index being zero. The higher the value of the index the higher the level of inequality in distribution.

This inequality measure can further be decomposed as follows:

$$I(x:y) = I_0(x:y) + \sum_{g=1}^{G} X_g I_g(x:y) \qquad (2)$$

Where: $I_0(x:y)$ is the between entity inequality and $I_g(x:y)$ is the inequality within entities. X_g is the entities actual share of water supply and G is the number of entities (i.e. 3 for districts and 5 for the DAWASA branches). Thus, $I_0(x:y) = \sum_{g=1}^{G} X_g \ln(X_g/Y_g)$ and $I_g(x:y) = \sum_{i \in sq} p_i \ln(p_i/n_i)$ where, $p_i = x_i/X_g$, $n_i = y_i/Y_{g(i \in sq)}$. Y_g is the entity's equitable share of water supply. These indices will show total inequality in water supply distribution for the city and its decomposition into inequality between and within entities. In this chapter the Theil index and its decomposition will be presented in three levels: (a) Overall Dar es Salaam (DSM) level, (b) district level and (c) DAWASA branches level.

3.4.2 Efficiency in Water Supply

In this chapter, we define efficiency in water supply to mean the ability of the water agency (DAWASA), to supply the available water to the city for basic needs (such as drinking, cooking, cleaning, bathing etc) to different districts, branches and wards in an equitable manner (i.e. in proportion to their population).

Water supply performance can be measured by the deviation of actual water supplied Q_s from the required water supply Q_r. This deviation called the performance error can be derived from Theil's measure of accuracy of forecast defined as:

$$e_c^2 = 1/n \sum (Q_r - Q_s)^2 \tag{3}$$

Where: e_c^2 is the measure of the overall performance error of the system due to shortfall deviations in water supply. This error could be further decomposed into measures indicating performance in terms of adequacy, equity or dependability and management capability as follows:

$$1/n \sum (Q_r - Q_s)^2 = (\overline{Q_r} - \overline{Q_s})^2 + (S_{Qr} - S_{Qs})^2 + 2(1-r) * S_{Qr} * S_{Qs} \tag{4}$$

where $\overline{Q_r}$ and $\overline{Q_s}$ are means of the desired and actual water supplied respectively, S_{Qr}, S_{Qs} are the standard deviations and "r" is the correlation coefficient of Q_r and Q_s,

and $r = (1/n \sum (Q_{ri} - \overline{Q_r})(Q_{si} - \overline{Q_s})) / (S_{Qr} * S_{Qs})$ (5)

The first term of the Right Hand Side (RHS) of equation (4) is a measure of inadequacy in water supply. This is the squared difference between the means of the actual and required amounts of water and thus indicates a measure of adequacy in water supply. This term will be zero if the averages of the required and actual water supplies are the same. Positive values of this term indicate errors in the water supply due to either excess or shortfalls of the required quantity. In the estimation of the extent of the error in water supply excess water supplies is not considered a problem. As such wards receiving excess water supplies are omitted from the analysis of performance error. Only those with shortfalls are taken into account. This error component is denoted by e_a.

The second term indicates the error due to unequal deviations in water supply. The standard deviation is a measure of uniformity of supply or a measure of dependability. The difference in the standard deviations reflects a measure of inequality of water supply in a spatial sense. This error term measure equity or indicate problems in distributing the available water among wards in an equitable manner in a spatial and temporal sense. This error is denoted by e_e.

The third term is the error due to incomplete co-variation of the actual and required water supplies. This term will be zero only if the correlation coefficient is unity i.e. the co-variance between Q_r and Q_s takes its maximum value. The term reflects a measure of management capability to implement a scheduled water supply program. If water supply schedule is according to demand, the correlation coefficient of Q_r and Q_s will be unity making the term zero. A positive value of this term will indicate either a lack of physical capacity to deliver the water or a lack of management capability. This component of the error is denoted by e_m.

By dividing equation (4) by the total error term we get proportionate measures of adequacy, equity or dependability and management capability, and

$$e_a + e_e + e_m = 1 \tag{6}$$

In this measure, a perfect performance occurs when the required water supply is achieved or surpassed i.e. $Q_r \leq Q_s$ in which case $e_s^2 = 0$.

3.5 Results and discussion

Following the objectives of this chapter the results of the analysis of equity and efficiency in the current water delivery system for the city, are summarized below.

3.5.1 Equity in water distribution

The current water supply and population distribution by district and branches are given in tables 3.1 and 3.2 respectively. Table 3.1 shows inequality in water supply between Districts.

Table 3.1 Water Consumption Distribution by districts (1998, 1997 and 1996).

District	Population %	Supply 1998 %	1997 %	1996 %
Kinondoni	54.41	54.69	54.30	53.20
Ilala	23.48	26.61	27.07	28.47
Temeke	22.11	18.61	18.63	18.33
Total	100.00	99.91	100.00	100.00

While both current and over time water supply in Kinondoni district is proportional to its population, supply in Ilala and Temeke districts is not. In both the current period and over time Ilala district is supplied proportionately more water than its proportionate population shares while Temeke district is supplied proportionately less water as compared to its population. This finding is consistent with the chronic water shortage that has been observed in Temeke relative to other districts in the city over time.

Table 3.2 reinforces the inequality shown above. Kawe branch with only 4.87% of the city population was supplied with 11.34% of the total city water supply in 1996 as compared to 31.19% of the population in Magomeni branch being supplied with 25.42% of the water. Ilala branch with 23.48% of the city population received 28.47% of the city water supply as compared to 18.33% supplied to 22.11% of the city population in Temeke branch. Over time, although the total percentage supply declined for Kawe and Ilala branches the figures are still higher than those called for by their populations. The increase in percentage consumption in Magomeni district does not change the results.

Table 3.2. Water Consumption Distribution by branch (1998, 1997 and 1996).

Branch	Population %	Supply 1998 %	Supply 1897 %	Supply 1996 %
Kinondoni	18.35	16.12	19.45	16.44
Kawe	4.87	10.35	11.17	11.34
Magomeni	31.19	28.22	23.68	25.42
Ilala	23.48	26.61	27.07	28.47
Temeke	22.11	18.69	18.62	18.33
Total	100.00	99.99	99.99	100.00

3.5.2 Water Supply Distribution by District

The estimated water supply in the city for the last three years is extremely low. While the city has the capacity to supply 181,000m^3 (181,000,000 liters/day) the estimated supply reflects only 0.49%, 0.47% and 0.65% of this capacity for 1996, 1997 and 1998 respectively indicating the extent of the water crisis in the city.

Tables 3.3, 3.4 and 3.5 show water consumption in the three administrative areas of DSM city i.e. Kinondoni, Ilala and Temeke districts, broken down to supply at DAWASA branches and ward level for the years 1998, 1997 and 1996. The three tables show there is inequality in water supply and therefore consumption between and within districts, DAWASA branches as well as between wards. From table 3.3, Kinondoni district's residents on average were supplied 0.65, 0.61 and 0.81 lpcd of water in 1996, 1997 and 1998 respectively while Ilala district residents were supplied 0.81, 0.70 and 0.91 lpcd of water in the same time period. The corresponding figures for Temeke district are 0.55, 0.51 and 0.68 lpcd. In all districts per capita water supply declined in

Table 3.3. Water consumption, Kinondoni district (lpcd).

Branch and wards	1998 lpcd	1997 lpcd	1996 lpcd	Avg
Kinondoni branch				
Wards: Msasani	0.66	0.51	0.59	0.59
Kinondoni	1.23	0.91	1.01	1.05
Mwananyamala	0.43	0.60	0.36	0.46
Average (Branch)	0.70	0.65	0.60	
Overall avg. branch				0.65
Kawe Branch				
Wards: Kawe	1.71	1.40	1.55	1.55
Average branch	1.71	1.40	1.55	
Overall aveg.branch				1.55
Magomeni branch				
Wards: Magomeni	1.44	1.09	1.27	1.27
Makurumla	0.09	0.07	0.08	0.08
Ndugumbi	0.29	0.23	0.26	0.26
Kigogo	1.56	1.12	1.37	1.35
Mabibo	0.17	0.14	0.15	0.15
Manzese	0.53	0.01	0.01	0.18
Ubungo	2.03	1.49	1.74	1.75
Average branch	0.73	0.46	0.54	
Overall avg. branch				0.58
Average district	0.81	0.61	0.65	
City Averages	0.92	0.69	0.76	

1997 then picked up in 1998. The between branches inequality is also substantial. While Ilala district's per capita supply is consistently above the city average i.e. 13% to 17% above (table 3.4), that of Temeke district is consistently below (15% to 18% below). The per capita supply in Kinondoni branch on the other hand is very close to the city average. Kawe branch has the highest per-capita water supply for the entire period averaging 1.6 lpcd followed by Ilala branch with an average of 0.81 lpcd. Kinondoni branch has an average of 0.65 lpcd while both Temeke and Magomeni branches have an average of 0.58 lpcd.

Table 3.4. Water consumption Ilala district/branch (lpcd).

Branch and wards	1998 lpcd	1997 lpcd	1996 lpcd	Avg
Ilala branch/District				
Wards: Tabata	0.62	0.46	0.52	0.53
Ilala	0.64	0.50	0.57	0.57
Mchikichini	0.05	0.04	0.03	0.04
Kipawa	0.16	0.12	0.15	0.14
Buguruni	0.17	0.12	0.14	0.14
Kariakoo	1.62	1.29	1.45	1.45
Jangwani	0.60	0.44	0.52	0.52
Gerezani	1.15	0.83	1.02	1.00
Kisutu	5.84	4.66	5.62	5.37
Upanga East	5.15	4.03	4.31	4.50
Kivukoni	1.22	1.00	1.14	1.12
Average	0.91	0.70	0.81	
Overall avg.branch				0.81
City Averages	0.92	0.69	0.76	

Inequality in water supply is also shown within branches. In Kinondoni branch for example, average supply ranges from 1.05 lpcd for the entire three years in Kinondoni ward to 0.46 lpcd in Mwanamyamala ward. The same inequalities are observed in Magomeni, Ilala and Temeke branches at varying degrees. In Magomeni branch, supply varies from an average of 0.08 lpcd in Makurumla ward to an average of 1.75 lpcd in Ubungo ward. In Ilala branch supply varies from an average of 0.04 lpcd in Mchikichini ward to an average of 5.27 lpcd in Kisutu ward. In Temeke it varies from 0.39 lpcd in Mtoni ward to 0.73 lpcd in Kurasini ward (table 3.5).

Table 3.5. Water consumption Temeke district/branch (lpcd).

Branch and wards	1998 lpcd	1997 lpcd	1996 lpcd	Avg
Temeke branch/District				
Wards: Temeke 14	0.77	0.59	0.62	0.66
Mtoni	0.45	0.33	0.39	0.39
Keko	0.59	0.44	0.46	0.50
Kurasini	0.85	0.63	0.70	0.73
Average branch/District	0.68	0.51	0.55	
Overall Average branch				0.58
City Average	0.92	0.69	0.76	

Overall, the per capita day water supply varies from an average of 5.37 liters per capita day (lpcd) in Kisutu ward to 0.04 lpcd in Mchikichini ward (i.e. 134.25 times difference) indicating a serious inequality in water supply in the city.

The above results are summarized by the Theil's inequality index in table 3.6. The overall total inequality for 1996 was 0.6500. Over time total inequality declined to 0.6020 in the year 1997 and to 0.4259 in the year 1998.

During the same time period, the water supply per day slightly decreased from 0.49% of the available capacity to 0.47% in 1997 then increased to 0.65% in 1998. The above inequality is decomposed in two levels: (a) district level and (b) branch level. Decomposition at districts level shows that the within district inequality is dominant over the entire period. In 1996 for example, 98.7% of the inequality was within district; the figure was 99.1% and 98.7% for the years 1997 and 1998. Decomposition at branch level shows that only 6.10% to 6.51% of the inequality is between branch while 93.49% to 93.90% is accounted for by within branch inequality.

Table 3.6. Theil's index of inequality and its decomposition.

Level	1998 Inequality	%	1997 Inequality	%	1996 Inequality	%
Between Districts	0.00	1.15	0.01	0.93	0.01	1.31
Within District	0.42	98.85	0.60	99.07	0.64	98.69
Total	0.43	100.00	0.60	100.00	0.65	100.00
Between Branches	0.03	6.10	0.04	6.51	0.04	6.00
Within Branch	0.40	93.90	0.56	93.49	0.61	94.00
Total	0.43	100.00	0.60	100.00	0.65	100.00

3.5.3 Performance Error Analysis

The results of the performance error analysis are summarized in tables 3.7, 3.8 and 3.9. Table 3.7 presents performance in terms of the percentage distribution of wards according to the level of water supply. Table 3.8 summarizes the performance analysis by districts and branches for the years 1996, 1997 and 1998.

3.5.4 Additive Decomposition Analysis

Table 3.7 shows that only 7.7% of the wards received water above 3.0 lpcd in 1996. The percentage is maintained up to the year 1998. The number of wards receiving between 1.00 and 1.99 lpcd declined from 30.8% in 1996 to 23.10% in the 1998. Those receiving between 2.00 and 2.99 lpcd increased from 0% in 1996 to 3.8% in 1998. The majority of the wards received less than 1.00 lpcd. The trend increased from 61.5% in 1996 to 69.25 in 1997 then declined to 61.6% in 1998. Overall, only 7.7% of the wards received more than 3 lpcd, 23.10% received between 1.00 and 1.99 lpcd while the majority i.e. 69.2% received less than 1.00 lpcd.

Table 3.7. Percentage distribution of wards according to the level of water supply

Liters per capita day (lpcd)	Overall %	1998 %	1997 %	1996 %
> 3.0	7.70	7.70	7.70	7.70
2 - 2.99	0.00	3.80	0.00	0.00
1 - 1.99	23.10	26.90	23.10	30.80
0 - 0.99	69.20	61.60	69.20	61.50
Total	100.00	100.00	100.00	100.00

This level of water supply is extremely low. The minimum water requirement for basic household needs such as drinking, cleaning, bathing etc. to maintain good health is estimated to be 100 lpcd.[2]

From table 3.8 Kawe surpassed the average equitable per capita water supply for the city in all three years therefore is the best performer. Temeke branch/district is the second best performer followed by Kinondoni branch accounting for 4.95% and 9.73% of the total error committed in 1996 respectively.

Table 3.8. Performance error analysis

Decomposable analysis	1998	1997	1996
Kinondoni District			
Kinondoni Branch	12.77	0.71	9.73
Kawe Branch	0.00	0.00	0.00
Magomeni Branch	55.67	70.74	64.93
Total District	68.44	71.45	74.66
Ilala Branch/District	26.98	24.25	21.15
Temeke branch/District	4.58	4.30	4.95
Total	100.00	100.00	100.76

[2] M. Falkenmark et all: "Macro-Scale Water Scarcity requires micro-scale approaches: Aspects of vulnerability in Semi-Arid development " Natural Resource Forum, vol.13, No. 4, Nov. 1989, pg. 258-267.

Magomeni branch committed the largest error of 64.93% in the same year. Performance over time fluctuated for both Kinondoni and Magomeni branches. Overall, performance for Kinondoni district improved over time. Performance in Ilala district deteriorated over time while that for Temeke district had minor fluctuations over time.

3.5.5 Performance Analysis by Districts and Branches

The results of the district and branch performance analysis are given in table 3.9 in term of error due to inadequacy e_a, equity or dependability e_e, management capability e_m, total error committed e_s^2, and the maximum possible error when no water is supplied (i.e. Max. e_s^2). The maximum possible error is higher than e_s^2 when $Q_s < Q_r$. The table also apportions the error among its three components and expresses the total error as a proportion of the maximum possible error. The lower the proportion the better is the performance. In 1996, the overall committed error for the entire city water supply system was 33.67% of the maximum possible error. Adequacy of the water supply, equity and management capability accounted for 63.1%, 0.07% and 36.9% of the total error committed respectively. Over time the overall total committed error as a percentage of the total possible error declined to 30.97% (1997) and to 26.85% (1998) indicating an overall performance improvement over time. The proportion of total error due to inadequate water supply decreased to 57.16% (1997) then increased to 64.07% (1998). The error proportion due to inequality and management fluctuated over time. Inadequate water supply stands out to be the major component of the error throughout the period under consideration accounting for an average of 61.43%.

Table 3.9. Perfomance Analysis by districts and branches

	1998					1997					1996				
	E_a	E_e	E_m	E	E/Max.E	E_a	E_e	E_m	E	E/Max.E	E_a	E_e		E	E/Max.E
Overall DSM	0.6407	0.0010	0.3583	1.0000	26.85	0.5716	0.0271	0.4013	1.0000	30.97	0.6305	0.0007	0.3688	1.0000	33.67
Kinondoni District															
Overall	0.7794	0.0046	0.2160	1.0000	36.03	0.6642	0.1111	0.2248	1.0001	43.38	0.7905	0.0105	0.1991	1.0001	49.29
Kinondoni Branch	0.7606	0.1276	0.1118	1.0000	15.46	0.6969	0.3031	0.0000	1.0000	0.99	0.6820	0.0992	0.2188	1.0000	14.77
Kawe Branch															
Magomeni Branch	0.8222	0.0000	0.1778	1.0000	51.87	0.8914	0.0271	0.0815	1.0000	76.01	0.8866	0.0246	0.0889	1.0001	75.85
Ilala District/Branch	0.5968	0.0439	0.3593	1.0000	45.03	0.5965	0.0378	0.0378	0.6721	46.68	0.5796	0.0340	0.3865	1.0001	44.27
Temeke District/Branch	0.7840	0.1913	0.0247	1.0000	3.73	0.7397	0.2383	0.0220	1.0000	24.11	0.8985	0.0947	0.0068	1.0000	4.28

District wise, the proportion of the total error committed to the maximum error possible declined over time in Kinondoni district indicating an improvement in performance. In Ilala and Temeke districts performance fluctuated over time with large fluctuations in Temeke than in Ilala branch. In Kinondoni and Temeke districts inadequacy error decreased between 1996 and 1997 and slightly increased in the 1998 while that of Ilala increased between 1996 and 1997 then remained constant thereafter. Overall inadequacy remained above 60% for the entire three-year period indicating increasing water scarcity over time. The error proportion due to inequality increased from 1.05% in 1996 to 11.11% in the year 1997 then decreased to 0.10% in the 1998 in Kinondoni district. Inequality increased consistently between 1996 and the year 1998 in Ilala branch while that for Kinondoni and Temeke branches increased then declined in the same period. The management error increased over time for Kinondoni and Temeke branches and slightly declined for Ilala branch.

CHAPTER 4

WILLINGNESS TO PAY FOR IMPROVED POTABLE WATER SUPPLY IN TANZANIA: CASE OF DAR ES SALAAM CITY

4.1 Introduction

Despite the fact that the demand for urban water supply has been increasing in most large and growing cities in the developing countries, water supply has either remained constant over time or have declined. Studies done in this area have shown inadequate cost recovery to be the most severe constraint to the development and maintenance of a sustainable water supply system. It has been argued that developing countries put emphasis on the implementation of water projects with donor support while the operation and maintenance (O&M) of the existing projects has often been neglected.

The pricing structure of water has also been far from satisfactory. Water pricing is done with little or no relation to the O&M costs of water authorities. Water prices has deliberately been kept far below what the supply and demand forces call for with the argument that such a pricing system will help the poor. Results of such price regimes have been disappointing and self-defeating in many countries where water authorities cannot provide adequate supplies at the set prices. The result of this practice has been the deterioration of water supply services, inadequate repair and maintenance, frequent interruptions, lack of capacity to expand service under increasing demand, poor quality water and increased water scarcity. This practice has been very costly to water users. In many cases they end up not receiving enough water, receiving poor quality water supplies or both. In turn consumers are forced to incur extra costs to treat water before use, construction of expensive storage facilities at their premises or going long distances in search for water increasing the chances for contamination and therefore jeopardizing their health situation.

The situation in most developing countries is even more peculiar because of the social norms associated with the way division of labor is traditionally done at the household level. In most of these countries particularly in Africa, the role of fetching water and the activities required for making it safe for household uses are predominantly performed by women (Reweta & Sampath 1997). In the current economic setting where the roles of women in society are changing as they participate more in the direct raising of the output of the economy as a whole, the need to minimize time spent on water related activities could no longer be ignored.

4.2 Objectives

The objectives of this chapter is to explore people's perception of both the quantity and quality of potable water supply in Dar es Salaam and their support for policies that will support increased quantity and improved quality of water. Survey results will be used to show how Dar es Salaam residents perceive both water quantity and quality, what factors influence their willingness to pay for increased quantity supplied; how much they are willing to pay for increased supply; as well as the premium that they are willing to pay for improved water quality. The chapter will also assess the influence of the gender of the head of the household on WTP.

4.3 Literature Review

Survey based valuations have been applied to common property resources or non excludable goods such as air and water quality, to amenity resources with scenic, cultural, ecological, historical or unique characteristics and to other situations where market prices are absent. The value attached to such goods and services are highly personal and individual specific i.e. different people will value the same good differently. The value an individual places on the good is therefore a measure of what he/she is willing to give up to acquire it.

The basic theory behind the willingness to pay valuation is that of an individual demand curve (Marshallian demand curve) and on the two Hicksian measures of consumer surplus i.e. the compensating variation and the equivalent variation. To measure benefits this method relies on estimating either the willingness to pay (WTP) or the willingness to accept compensation (WTA). These estimates can be derived directly from a bidding game approach or inferred from choices made among various bundles of goods. Since both methods attempts to define the consumer demand curves, they take full account of consumer surplus in estimating benefits.

There is a substantial literature on theoretical application of CVM. Major recent works includes Kanninen (1995), Howe (1994), Jordan and Elnagheeb (1993), Cooper (1993), Whittington et al (1992), Shultz and Lindsay (1990), Loomis (1990), Mitchell and Carson (1989) and Desvousges (1987). Although many studies have been done using

CVM, its application to water problems has mostly been done in the developed countries and very little has been done in the developing countries. The few studies that have been done in these countries include V. K Smith et al (1991), Whittington et al 1989, 1990, 1991, 1992 and Mujwahuzi (1993).

Literature on WTP models has shown variation in formal education, age, sex, occupation, income and other socio-economic characteristics to have influence on users' willingness to pay. A common practice in contingent valuation studies has been to use a multivariate technique to determine how the socio-economic characteristics of the respondents and other variables affect the WTP bids (Mitchell and Carson, 1989). Such an analysis has two main purposes: First is to determine the correlation between the WTP bids and these variables. If the WTP bids are correlated with the variables suggested by economic theory then it will increase our confidence that the WTP bids reveals information about respondents preferences and are not simply random numbers. Secondly, models of the determinants of respondents WTP bids can be used to predict how changes in the social economic characteristics will affect the demand for the good or service offered (Whittington, Briscoe, Mu and Baron, 1990). The willingness to pay for increased supply of potable water in Dar es Salaam will include these personal and social-economic attributes.

A variety of formats have been used in contingent valuation (CV) studies. The open-ended format where a respondent is asked to report his/her willingness to pay has often been criticized by CVM researchers (Jordan and Elnagheeb 1993). Some argue that people give more meaningful responses to dichotomous type questions such as "are you willing to pay at least $ 50.00 for ..." rather than to open ended questions such as: how much are you willing to pay for..." (Hanneman, 1995). The dichotomous choice format has also become common in CV studies (Jordan and Elnagheeb 1993). The yes or no responses to dichotomous questions format questions are used in a regression model to calculate the average and or the median WTP. Although this method is easy for the respondents it has been argued that the information in the responses is diffuse in that all that a researcher knows is whether the respondent's willingness to pay is more or less than the offered amount (bid). It therefore requires a large sample size and a well-specified empirical model to estimate individual WTP (Cameroon and Huppert in Jordan, 1993).

Another question format is the checklist often called the payment card developed by Mitchell and Carson (Mitchell and Carson, 1989). In this format a respondent is offered a set of values and asked to circle the highest he or she is willing to pay for the public good in question. The information received from the respondent is that his/her WTP lies between the circled value and the next higher value. The advantage of this method is that it provides visual aid to respondents, which enable them to scan a detailed set of value intervals quickly. The information obtained with the checklist is also more precise as it provided the respondents willingness to pay interval and therefore does not require as large a sample as in the referendum method. WTP estimates from the checklist appear at least as reliable as when respondents state their maximum WTP directly (Loomis, 1990). The advantage of dichotomous choice CVM in terms of the reduced burden to the respondents can therefore be enjoyed without any loss in reliability of the willingness to pay estimates. In this study the checklist method will be used.

4.4 Methodology

This chapter employs the contingent valuation method (CVM) to estimate the willingness to pay for increased water supply in Dar es Salaam city, Tanzania. The CVM is a useful technique for eliciting value of nonmarket goods. The method uses survey and question technique to estimate the value that individuals place on changes in the quantity or quality of a natural resource in the context of a hypothetical market.

4.5 The Model

Previous empirical studies have shown that valuation distributions are frequently skewed (Jordan and Elnagheeb, 1993). As such, the OLS technique used to estimate linear relationships would be inappropriate in these models. The model specification used in this paper closely follows that used by Cameron and Huppert, 1989, and Jordan and Elnagheed 1993.

The $i-$th households true WTP, Y_i, is unobserved and can be expressed as:

$$\ln Y_i = \chi_i' \beta + \varepsilon_i \qquad (1)$$

where: χ_i = vector of explanatory variables, β_i = vector of parameters and ε_i = independently normally distributed error term with mean equal to zero and variance σ^2, $\ln Y_i$ = the natural logarithm of Y_i. The maximum likelihood (ML) method described below will be used to estimate equation 1.

From the checklist questions, the true maximum WTP for household i given by Y_i will lie between the chosen value (p_{il} the lower bound of the WTP interval) and the next higher value (p_{iu} upper bound). The $\ln Y_i$ will therefore lie between the $\ln p_{il}$ and $\ln p_{iu}$.

Using equation 1 we can standardize each pair of interval thresholds for $\ln Y_i$ and the probability that Y_i will be between p_{il} and p_{iu} i.e. $\Pr(p_{il} \le Y_i < p_{iu})$ be written as:

$$\Pr(p_{il} \le Y_i < p_{iu}) = \Pr(\ln p_{il} \le \ln Y_i < \ln p_{iu})$$
$$= \Phi[(\ln p_{iu} - X_i'\beta)/\sigma] - \Phi[(\ln p_{il} - X_i'\beta)/\sigma] \qquad (2)$$

where $\Phi[.]$ is a standard normal distribution function. The joint probability density function (p.d.f) for n independent households can then be interpreted as a likelihood function defined over the unknown parameter β and σ (implicit in Z_{iu} and Z_{il}) as defined below. The corresponding log likelihood function is given by

$$\ln L = \sum_{i=1}^{N} \ln[\Phi(Z_{iu}) - \Phi(Z_{il})] \qquad (3)$$

where: $Z_{iu} = (\ln p_{iu} - X_i'\beta)/\sigma$ and $Z_{il} = (\ln p_{iu} - X_i'\beta)/\sigma$.

The above likelihood function will be maximized with respect to the unknown parameters β and σ using the ML methods. The expected WTP, $E[Y_i]$ will be obtained by the equation: $E[Y_i] = \exp(X_i'\beta + \sigma^2/2)$ (4)

The median WTP will be given by the equation

$$\text{Median} = \exp(X_i'\beta) \qquad (5)$$

while the conditional WTP will be given by

$$E[Y_i | p_{il} \le Y_i < p_{iu}] = \exp(X_i'\beta + \sigma^2/2) * \left\{ \frac{\Phi(Z_{iu} - \sigma) - \Phi(Z_{il} - \sigma)}{\Phi(Z_{iu}) - \Phi(Z_{il})} \right\} \qquad (6)$$

Equations 4 to 6 were used to calculate the mean, median and conditional WTP for improvement of potable water supply for the city of Dar es Salaam, Tanzania. The

WTP will be used to estimate the aggregate WTP for improved water supply in Dar es Salaam.

4.6 Data and Survey Design

Data used in this study was obtained from a household survey of Dar es Salaam residents, which was conducted in the summer of 1998. Households that were surveyed were selected using a stratified random sampling procedure. A total of 211 households were selected from the three administrative districts in the city. Personal interview method was used. Out of the 211 households surveyed, 38 households depended on household connections at their premises as their main supply source as compared to 43 households that depended on vendors and 60 households on yard connections. In general slightly more than 80% of the sample depended on multiple sources to satisfy their daily water requirements.

Respondents were presented with the following situation before they were asked for their WTP:

> "Suppose a significant improved water supply system is made available to the city. After this improvement all households will benefit by getting water supply 24 hours a day, water will be clean, pressure will be satisfactory and the system will be reliable. Households will be able to use as much water as they wanted for all non-commercial purposes."

Respondents were then asked to circle from a set of pre determined values the most that they will be willing to pay above their current monthly water bill. The checklist interval frequencies are summarized in table 4.1. The question read as follows:

> "If the above-described system became available THE MOST I will be willing to pay ABOVE my current monthly bill is (Please Circle ONE answer): Tsh. 0.00, Tsh. 250.00, Tsh. 500.00, Tsh. 750.00, Tsh. 1000.00, Tsh. 2500.00, Tsh. 5000.00, Tsh. 8000.00, Tsh. 10000.00 or Tsh. 14000.00"

Table 4.1: Distribution of Willingness to pay

WTP Interval Tsh	Frequency	%
0 < 250	25	11.8
250 < 500	62	29.4
500 < 750	19	9.0
750 < 1000	21	10.0
1000 < 2500	23	10.9
2500 < 5000	17	8.1
5000 < 8000	27	12.8
8000 < 10000	4	1.9
10000 < 14000	13	6.2

Sample size = 211 households Interval i – j means the true WTP is greater than or equal to i but less than j. The respondent circled value i.

Respondents were also asked questions to determine their perception of the water quality. They were then asked the following question about their WTP for improved water quality:

> "Suppose that the water authority also want to improve water quality. This improvement will make your water supply safe to drink directly from the tap and it will not be necessary to boil and filter water before use. This improvement will increase your monthly water bill."

Respondents were then asked to circle from a set of percentage values the most that they will be willing to pay above their expressed WTP to improve water quality. The question reads as follows:

> "If the above improvements are made for water quality, THE MOST I will be willing to pay ABOVE my expressed WTP (as a percentage of my expressed WTP) is (Please Circle ONE answer): 0.0%, 5%, 10%, 25%, 50%, 75%, 100%, 200%, More than 200%."

Other survey questions were used to collect respondents' socioeconomic and demographic characteristics. Table 4.2 lists and describes the independent variables used in the analysis.

Table 4.2: Variables used in the Analysis

Variable	Description
S1	Dummy for gender of the respondent: S1 = 1; if the respondent is a male, and 0 otherwise
Age	Age of the respondent in years
TBILL	Total bill paid for water by the household (including extra money paid for water from other sources)
HWRD	Number of hours a household receives water in a day
E2	Dummy variable for educational level: E2 = 1 if the respondent has post Secondary School Education and 0 otherwise
LNINC1	Logarithm of income

4.7 Results and discussion

The MLE estimates for WTP equations for Dar es Salaam city are presented in tables 4.3 and 4.4. In both tables, the coefficients for gender, total monthly water bill, education and income are positively related to the WTP. In table 4.3, all variables are significant at 0.95 level with exception of gender and education. When outliers are removed from the estimation, the coefficient for education become significant at 0.90 level.

Table 4.3: ML Estimates for DSM With Outliers*

Variable	Coefficient	t-Ratio
Constant	3.663374	1.6946
S1	0.230614	1.0920
AGE	- 0.024534	- 3.1070
TBILL	0.000043	2.1590
HWRD	- 0.033730	- 3.1440
E2	0.350625	1.2170
LNINC1	0.371669	2.3550
SIG	1.280073	14.8620
Log Likelihood function	- 455.15	N = 211

* Outlier = Households with WTP greater or equal to .01 of their monthly income

The cut off for outliers has been done arbitrarily using a ratio of the WTP per year (i.e. the circled WTP value multiplied by 12) divided by the household annual income. If the ratio was greater than 5 percent an outlier was identified (Jordan, et.all. 1993). Studies on water vending activities elsewhere in Africa shows that households spend as much as 9 percent of their income on water vending activities while households in Onisha, Nigeria pay water vendor twice the operations and maintenance (O&M) cost of a piped distribution system (Whittington et al 1992). Poor households pay more for water than rich households both in absolute terms and as a percentage of their income. Low income households spend 18 percent of their incomes on water during the dry season as compared to 2 to 3 percent for the upper income households, contradicting earlier beliefs that households can only afford 3 to 5 percent of their incomes for improved water services (Whittington et al 1991). Other recent studies on water vending activities support this finding. It has been shown that the poorest households in Port-au-Prince Haiti spend as much as 20 percent of their income on water during dry season (Fass 1988, in Whittington 1991). An average household spends about 9% of its income on water from vendors in Ukuda Kenya (Whittington, 1990). The evidence from water vending studies done in similar low income countries show that the poor households are already paying more for water than the high income households.

Given the above, it is evident that in developing countries households pay much higher a percentage of their income for water than the 5 percent. The arbitrary cut off for outliers used in this study was 10 percent, i.e. any household who's expressed WTP was equal to or greater than 10 percent was considered an outlier.

The removal of outliers reduced the sample size by 39 households. The coefficient for gender remained insignificant even after removal of outliers (table 4.4). It may therefore be asserted from this study that gender of the head of the household does not have a strong influence on the willingness to pay of a household. The Age of the respondent is significant and negatively related to the WTP in both equations indicating that younger respondents has a higher willingness to pay for increased water supply than older respondents. Education level is positively related to WTP indicating that respondents with higher levels of education are willing to pay more for increased water supply than those with lower levels of education. These results are similar to those reached by Jordan et al. (1993).

Table 4.4: ML Estimates for DSM
Without Outliers

Variable	Coefficient	t-Ratio
Constant	1.207142	0.7700
S1	0.254221	1.4013
AGE	- 0.013967	- 2.0060
TBILL	0.000030	1.6866
HWRD	- 0.021558	- 2.3582
E2	0.415465	1.8437
LNINC1	0.558428	3.8753
SIG	0.997080	10.7430
Log Likelihood function	- 347.46	N = 172

The number of hours water is received in a day is significant and negatively related to the WTP indicating that residents will be willing to pay less for improvement if the current system would make water available for longer hours i.e. the higher the number of hours water is received in a day, the less the need for improvement of the system. Total bill is significant and positively related to the WTP i.e. the higher the current water bill the higher the demand for an improved water supply system. The coefficient on the logarithm of income is positive and significant indicating that WTP for increased water supply will increase as income increase. This coefficient can also be interpreted as the elasticity of willingness to pay. Before rejecting outliers a 10 percent increase in income will result in about 3 percent increase in the willingness to pay for increased water supply. The increase is about 6 percent after rejecting outliers.

4.7.1 The WTP Estimates

A simple way of calculating the mean sample WTP would be to use the distribution of WTP given in table 1 in the following equation:

$$E(WTP) = \sum_{i=1}^{9} w_i p_i \tag{7}$$

where EWTP is the mean (expected) willingness to pay, w_i is the lower bound of the i-th interval (column 1 of table 1) and p_i is the corresponding relative frequency. This method will however underestimate WTP because by definition a respondent is willing to pay the lower bound value (the circled value) or more but not the upper value (Jordan et.all; 1993). To avoid this problem, equations 4, 5 and 6 will be used to estimate the mean; median and conditional mean WTP respectively for each individual household. The conditional mean refers to the expected WTP based on the fact that the true WTP for each household is restricted to fall between the circled value i.e. the lower bound and the next higher value estimations are presented in table 4.5.

From table 4.5, the median WTP changes by only 10 percent after correcting for outliers as compared to 28 and 52 percent respectively for the mean and conditional WTP. This result supports the robustness of the median measure with respect to outliers (Jordan, et.all, 1993, Devore, 1987). The table also shows that on average residents of Dar es Salaam city are willing to pay Tsh. 2094.00 above their current monthly water bill for increased potable water supply.

Table 4.5: Sample Average Willingness to Pay (Tsh)

	With Outliers			Without Outliers		
Variable	Total	Female	Male	Total	Female	Male
WTP						
Mean	2685	2239	2958	2094	1634	2366
Median	936	856	988	1032	875	1212
Conditional mean	2432	2305	2510	4634	2770	5738
Premium for quality						
Average	537	481	571	547	608	444
Median	125	125	188	188	125	188

Households were also asked questions regarding water quality in the city. About 92 percent of the households surveyed reported that they usually boil their water before use because of health concerns. In table 4.5, residents are willing to pay on average a premium for improved water quality of Tsh. 547 per month over and above their expressed mean WTP for improved water supply. The current mean total monthly water bill is about Tsh. 6,777. If the WTP amount is included the average monthly bill will be Tsh. 9,411, which is about 11 percent of the average monthly income.

4.7.2 Aggregate WTP

Although the median is a more robust measure to errors and outliers than the mean (Devore, 1987), in a skewed value distribution the median is not equal to the mathematical expectation of the maximum WTP (Jordan et.al. 1993). With the difference between the median and the mean being large, the median can be used as the lower estimate of the WTP for Dar es Salaam households for improved water quantity and quality. With a median WTP of Tsh. 1032 per month above the current normal monthly bill the annual median WTP per household is Tsh. 12,384. The mean household WTP per year is Tsh. 25,128.

With a population estimate of 1,456,442 residents in Dar es Salaam for the year 1988 (authors projections) and an average household size of 7 (survey results), we have a total of approximately 208,000 households in Dar es Salaam city. Using the median, the aggregate WTP for improved potable water supply is Tsh. 2,275m per year. The aggregate premium for improved water quality is Tsh. 505m per year. Total WTP for both improved supply and quality is therefore Tsh. 2,576m a year (i.e. US$ 3.2m). This figure gives a conservative estimate of the WTP since a smaller median was used instead of the higher mean. Using the mean the aggregate WTP per year is about Tsh. 5,227m for improved supply and Tsh. 1,365m for improved water quality. The aggregate WTP for the city of Dar es Salaam per year (i.e. for both improved quantity and quality) therefore stands at Tsh. 6,592m per year, an equivalent of US$ 8.2m.

CHAPTER 5

ESTIMATION OF THE BENEFITS OF INCREASED POTABLE WATER SUPPLY IN DAR ES SALAAM CITY

5.1 Introduction

The supply of potable water in the city of Dar es Salaam is at a critical stage. The city has been besieged with severe water shortage that has deteriorated over time for the last several decades. Given the available water produced by Dar es Salaam Water and Sewerage Authority (DAWASA), the per capita day water consumption in 1998 was 0.92 liters (Reweta and Sampath, 2000). This amount is less than 1% of the daily requirement to meet basic household needs and maintain a good health i.e. 100 lpcd (M.Fulkenmark et.all, 19889). The need for increased water supply for the city is therefore critical and has a potential for an increased welfare of the residents of Dar es Salaam as shown in this paper.

5.2 Objectives

The objective of this chapter is to evaluate the benefits of increased potable water supply in the city of Dar es Salaam by estimating the Consumer Surplus (CS) as well as the Producer Surplus (PS) that will result from such an improvement.

5.3 The Model

Classical economic theory holds that for any marketable product or commodity, the intersection between the demand and supply functions will generate an equilibrium price at which the product will trade. Once this equilibrium is attained, an increase in the supply will cause a shift in the supply function to the right. With a downward sloping demand function, the shift will result in an increase in economic welfare through a large consumption of the product in question at a lower price (cost) and or an increased consumption of other products. In this chapter, the supply function by vendors and other private suppliers is assumed to remain constant. However, in response to increased demand, quantity supplied increases from g_0Q_0 to g_0Q_1. This increase in supply is here defined as an improvement or increased efforts to increase water supply by vendors and private suppliers in response to increased demand. The distribution of the welfare gain between producers and consumers will depend on the price elasticities of the respective demand and supply functions (Hayami and Herdt, 1977).

To evaluate the welfare implications of an increased potable water supply for the city of Dar es Salaam, the Hayami and Herdt model (1977 later refined by Ahmed and Sampath (1992) are used and modified to fit an urban water problem. The model which utilizes the Marshallian partial equilibrium analysis, use shifts in demand and supply functions to evaluate the gains and losses to consumers and producers – in this case DAWASA and private vendors.

In figure 5.1, D_0D_0 and D_1D_1 represents aggregate potable water demand for the city at present time and in some future date respectively. The demand is expected to increase over time as a result of an increase in income and population both through

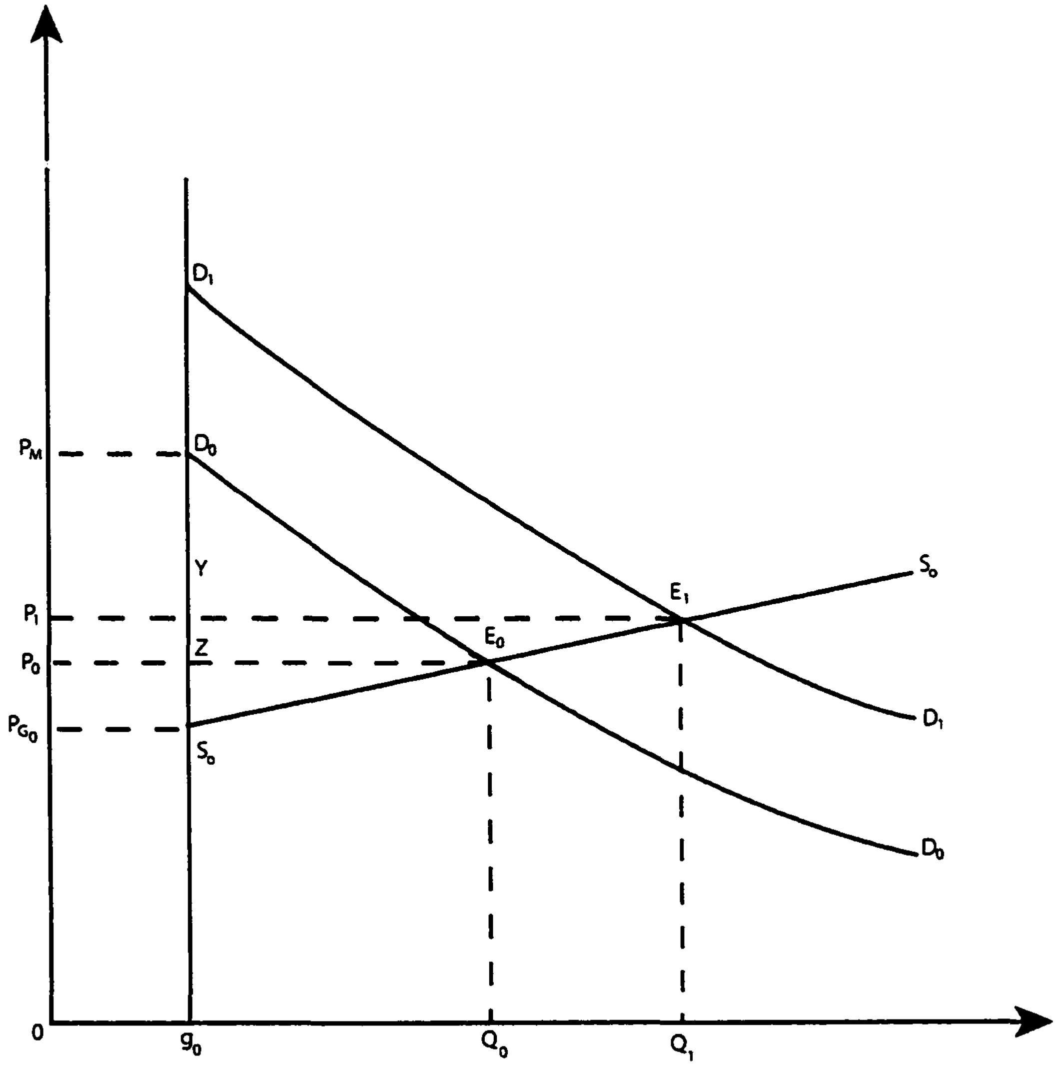

Fig 5.1: A model to estimate the Welfare benefits of increased potable water Supply for Dar es Salaam city

migration and the natural growth. S_0S_0 represent water supply function by vendors and private suppliers. The assumption here is that at price P_m quantity demanded from private suppliers is zero. The quantity demanded increases as price declines. $0g_0$ is the quantity of water produced by the water authority (DAWASA) and is fixed. This water is sold at government set price P_{G0}. At this price supply from the private suppliers is assumed to be zero and increases as price increases. The equilibrium E_0 is established at price P_0 and quantity $0Q_0$ with quantity g_0Q_0 supplied by private suppliers. E_1 is the new equilibrium taking into account the effects of increased income and population over time and the completion of supply improvements by private suppliers. The consumer surplus and producer surplus before and after improvements are given by areas D_0E_0Z, ZE_0S_0, D_1E_1Y and YE_1S_0 respectively. The change in CS is given by the area $D_1E_1Y - D_0E_0Z$. The change in PS is given by $YE_1S_0 - ZE_0S_0$.

Mathematically, the model assumes a constant price elasticity of demand and that the initial market demand function is given by:

$$Q = \beta p^{-\varepsilon} \tag{5.1}$$

where p and Q are price and quantity of water demanded respectively; ε is the constant price elasticity of demand and β is a constant.

The supply function also under constant elasticity assumption is given by

$$Q = \alpha p^{\delta} \tag{5.2}$$

where p and Q are price and quantity supplied of water respectively; δ is the constant price elasticity of supply.

From equation 5.1 and 5.2, the equilibrium price before improvements is given by

$$P_0 = \left(\frac{\beta}{\alpha}\right)^{1/\delta+\varepsilon} \qquad (5.3)$$

The rate of increase in the demand for water over time will depend on the growth rates in population and per capita income. Let z represent the shift in the demand function, so that:

$$z = N + \eta Y \qquad (5.4)$$

where: N is the rate of change in total population

η is the income elasticity of demand

Y is the proportional change in per capita income

Assuming a z proportional shift in the demand function resulting from changes in population and income we have the following new demand function:

$$Q = \beta(1+z)p^{-\varepsilon} \qquad (5.5)$$

With the new demand function, the new equilibrium prices after improvements can be derived by equating the respective demand and supply functions and solving for p as follows:

From equations 5.2 and 5.5 we solve for P_1 as follows:

$$\beta(1+z)p^{-\varepsilon} = \alpha p^{\delta}$$

$$\frac{\beta(1+z)}{P^{-\varepsilon}} = \alpha p^{\delta} \Rightarrow P_1 = \left(\frac{\beta}{\alpha}\right)^{1/\delta+\varepsilon}(1+Z)^{1/\delta+\varepsilon}$$

$$P_1 = P_0(1+Z)^{1/\delta+\varepsilon} \qquad (5.6)$$

$$\text{since } P_0 = \left(\frac{\beta}{\alpha}\right)^{1/\delta+\varepsilon} \text{ (from 5.3)}$$

The equilibrium quantities of water at the initial time period and the future period taking into account the supply improvement are obtained from equation 5.2 by substituting P_0 and P_1 then solve for Q:

$Q = \alpha p^{\delta}$ and $P_0 = \left(\frac{\beta}{\alpha}\right)^{1/\delta+\varepsilon}$ form 5.2 and 5.3. Substituting for P we get:

$$Q_0 = \alpha\left[\left(\frac{\beta}{\alpha}\right)^{1/\delta+\varepsilon}\right]^{\delta} = \alpha\beta^{\delta/\delta+\varepsilon}\alpha^{-\delta/\delta+\varepsilon} = \alpha^{\varepsilon/\delta+\varepsilon}\beta^{\delta/\delta+\varepsilon} \qquad (5.7)$$

Substituting for P_1 in 5.2 we get

$$Q_1 = \alpha\left[P_0(1+Z)^{1/\delta+\varepsilon}\right]^{\delta}$$

Substituting P_0:

$$Q_1 = \alpha^{\varepsilon/\delta+\varepsilon}\beta^{\delta/\delta+\varepsilon}(1+z)^{\delta/\delta+\varepsilon} = Q_0(1+z)^{\delta/\delta+\varepsilon} \qquad (5.9)$$

From figure 5.1, the change in CS is given by

$$D_1E_1Y - D_0E_0Z \qquad (5.10)$$

Denoting the demand functions by D and total water supply by Q; the change in CS is given by the following equation:

$$\Delta CS = \left\{\int_{g_0}^{Q_1} D_1\partial q - P_1(Q_1 - g_0)\right\} - \left\{\int_{g_0}^{Q_0} D_0\partial q - P_0(Q_0 - g_0)\right\} \qquad (5.11)$$

To simplify the above equation we let λ represent the ratio of total water sold by the private suppliers to the total amount produced so that $\lambda = \left(\frac{Q - g_0}{Q}\right)$ and $g_0 = Q_0(1-\lambda_0)$ in the initial time period and $g_0 = Q_1(1-\lambda_1)$ in the future period and after supply improvements are completed. Equation 5.11 can therefore be rewritten as:

$$\Delta C = \left\{\int_{g_0}^{Q_1} D_1\partial q - \int_{g_0}^{Q_0} D_0\partial q - P_1Q_1\lambda_1 + P_0Q_0\lambda_0\right\} \qquad (5.12)$$

Integrating 5.12 and simplifying we get:

$$\Delta CS = P_0Q_0\left\{\frac{1}{v}\left[u(1-(1-\lambda_1)^v - (1-(1-\lambda_0)^v\right] - u\lambda_1 + \lambda_0\right\} \qquad (5.13)$$

where: $u = (1+Z)^{\delta+1/\delta+\varepsilon}$ and $v = 1 - 1/\varepsilon$

(A complete treatment of equation 5.13 is in appendix 1)

From figure 5.1, supplier's revenue SR under initial conditions and in the future period is given by

$$\Delta SR = P_0 Q_o (u\lambda_1 - \lambda_0) \qquad (5.14)$$

The change in cost of production as a result of improvements is given as

$\Delta C =$ Area $S_0 E_1 Q_1 g_0 - S_0 E_0 Q_0 g_0$, which can be presented mathematically as

$$= \int_{g_0}^{Q_1} S_0 \partial q - \int_{g_0}^{Q_0} S_0$$

$$= P_0 Q_0 w(u-1) \qquad \text{where } w = \frac{\delta}{\delta + 1}$$

The change in SR is therefore given by:

$$\Delta SR = P_0 Q_0 \left[u(\lambda_1 - w) - (\lambda_0 - w) \right] \qquad (5.15)$$

The net benefit is given by the sum of the change in consumer surplus and supplier's revenue.

The above model is used to analyze the situation in the city of Dar Es Salaam. The initial situation referring to the status quo in which the quantity $0Q_0$ is supplied to the city residents by both DAWASA and private suppliers. The future period is assumed to be the time it would take DAWASA to complete water supply improvements to be able to supply enough water to meet city demand. Options for the city and conditions under which they may be prudent are examined.

5.4 Data

The year 1998 is used in this study as the base. According to the 1997 World Development Report, the per capita GDP for Tanzania is given as US $ 120. The GDP growth rate is 4.0% (Bank of Tanzania 1999). It is assumed that improvement by DAWASA will take 5 years to complete. In local currency the per capita GDP will grow from Tsh.96, 000 (1988) to Tsh. 116,799 in year 2003. The ratio of total water sold to the amount produced is assumed to be 80% before and after improvement.

The price elasticity of demand range from –0.287 in Manila (Palencia, 1984) to 0.448 in Cassablanca (Lahlou, 1998). The mid point of 0.362 will be used in this study. The income elasticity is estimated to be 0.558. Price elasticity of supply is assumed to be 1.21. A sensitivity analysis will be done with supply elasticities of 0.8 and 1.5 to see if results are sensitive to change in this parameter.

The domestic water consumption per day was estimated to be 128,180 cubic meters per day (JICA, 1990), giving an average of about 184 liters per capita day. Assuming this average remained constant over time, consumption in 1998 would have been about 330,000 cubic meters per day, out of which about 140,000 would have been supplied by DAWASA. The private suppliers therefore supplied about 190,000 cubic meters per day. The average price of water from private suppliers is estimated to be Tsh. 100 per 20-liter container (Marianne, unpublished), which translates to Tsh. 5000 per cubic meter.

5.5 Results and discussions

The results of the distribution of benefits from increased water supply are summarized in table 5.1. The results show that both the changes in consumer and producer surpluses are positive. Sensitivity analysis was done to see if the results are sensitive to changes in the price elasticity of supply. The results show that both the change in consumer and producer surpluses and therefore the change in total welfare increase with decreasing elasticity of supply.

From table 5.1, there is no doubt that the welfare of the residents of Dar es Salaam will be improved if water supply is to be increased in the city. At the current price level P_0 total welfare will increase by about Tsh. 1,965 bn over the five year period an average of Tsh. 339 bn a year. Two scenarios are apparent in this analysis. One is where DAWASA, or a private company, or a joint venture between DAWASA and some private company step in and produce $0Q_1$. The second scenario is one where the status quo remains. The choice of the best scenario for the long-term welfare of the residents will depend on the cost benefit analysis of the two scenarios.

A simple comparison of the two choices show that the first scenario will minimize the role of vendors in supplying water to the city if not eliminating them all together. The main costs involved here will be the loss of income to current vendors and their families. The main advantages will include taking advantage of economies of scale in production as well as production of a standardized product i.e. water in this

Table 5.1: Distribution of benefits from increased water supply

	Elasticity of Supply			
	$\varepsilon_s = 1.5$	$\varepsilon_s = 1.21$	$\varepsilon_s = 0.8$	$\varepsilon_s = 0.4$
Change in Consumer Surplus	1,959	1,965	1,978	2,050
Change in Producer Surplus	1.3	1.7	2.7	4.7
Total Welfare Change	1,960.3	1,966.7	1,980.7	2,054.7

case, of a known quality. The second scenario perpetuates the status quo. While employment and income to current vendors is assured, the cost to society as a whole due to lack of control particularly on quality can be substantial. In 1991 for example, the city of Lima in Peru was hit by a cholera epidemic as a result of poor water and sanitation facilities. A total of 2,600 people died out of 320,000 infected. The fishing industry in Peru collapsed and tourism fell considerably. With the money lost in exports, Peru could have provided a water and sanitation system that would have supplied the entire population of its capital, Lima (UN, 2000). Under increased water scarcity, water quality particularly for the poor will continue to deteriorate increasing the cost both in terms of the price and the cost of purifying water before use and illnesses associated with the use of poor quality water.

The need for improving the supply of water is clear. An interesting question may be who should undertake the improvement. There is a need to have a formalized water supply system for the city in which sensitive issues such as quality and quality control can be assured and monitored.

CHAPTER 6

CONCLUSIONS AND POLICY RECOMMENDATIONS

6.1 Introduction

Many citizens in the developing countries and transition economies are excluded from enjoying safe and reliable water supply. In many cities, between 30 and 60 percent of the population have no formal water connections (Cowen and Cowen). Residents therefore resort to wells, buckets, supply by tank-trucks and physical transport of water through human labor.

This work has reviewed issues surrounding urban water supply in developing countries. Specifically it has examined issues of equity, efficiency, cost recovery, willingness to pay for increased water supply and improvement of water quality as well as estimating the net benefits of improved (increased) potable water supply to both the consumers and water suppliers. Although the focus was on two geographic areas in Tanzania, the results can be generalized to give a picture of the extent of urban water supply in the country.

6.2 The Hai Water Project

Results from the Hai Water Project show that public taps are not equally distributed in the project area. This inequality is more pronounced across villages and across townships than between villages on the one hand and townships on the other. In future project expansions, it is recommended that this issue be addressed so as to improve services to the beneficiaries. Distribution of PT's should be based on equal number of households per tap or equal number of persons served by one public tap across the project area.

Data management seemed to be a problem in the 1995 period as shown by the wide fluctuations of per unit water prices from the set prices. Although the problem has been corrected in most part, efforts have to be made to ensure that accurate data is kept to avoid such problems in the future.

Overall, timely collection of bills seems to be the major problem facing the project followed by "under-collection" and lastly lack of dependability in bills collection rates. To improve performance these problems need to be addressed. Efforts to improve collections on a timely manner should be increased. Identifying the PTs and HH that delay payment and dealing with them individually, and /or stepping up campaigns to sensitize the importance of bill payments for the sustainability of the project may help.

Project performance deteriorated over time. This is typical of many projects in the developing countries where projects performs well in the first few years, then deteriorate in later years and then totally collapse in some cases. This problem needs to be acknowledged and dealt with accordingly if the project is to sustain itself.

Despite the above problems, the project has performed well as reflected by coverage of O&M costs from bills collections, which is key to the sustainability of any project. Given the expressed willingness to pay and the actual performance the project stands a chance to perform even better by improving collection efficiency. Since many projects in developing countries fail to sustain themselves because they cannot cover their

O&M costs, the Hai water project provides a good example of a sustainable rural/urban water supply project to be emulated not only in Tanzania but elsewhere in the developing countries.

6.3 Performance Evaluation of Water Supply System in Dar es Salaam city

The city of Dar es Salaam is in a very serious water supply crisis. Both the adequacy measures and the average per capita day amounts supplied by the water authority show this. The average per capita day supplies of less than 1.0 liters is less than one percent of the estimated daily requirement to maintain a healthy life style and less than the minimum requirement for survival. These findings strongly support the observation that residents of Dar es Salaam are heavily dependent on other sources of water supply for their survival. The quality of water from those sources in terms of treatment and therefore its safety to the population is an issue that should feature high on the city and government agenda. There is an urgent need for the city and the Government to look for alternative sources of water supply to solve the current supply crisis and maintain water supply standards for the city. The government needs to consider either full privatization or a private-public arrangement for improving the availability of capital for investment purposes as well as for managing efficiently and equitably the water supplies.

A comparison of branch performance reveals that Kawe branch is the best performer with the lowest proportionate error committed to the maximum error possible throughout the period under consideration. Overall performance of the system improved over time. Inadequate water supply for the whole system is a major issue and has increasing over time indicating increasing water scarcity. There is a need therefore to start searching for new sources of water supply for the city. Repair and maintenance of the current system is but a temporary solution.

On equity, water delivery is not equally distributed between the three administrative districts in the city. Ilala district receives more water than called for by its population size while Temeke district receives less water than what the population size calls for. Expansion or improvement of the city water supply system should take this fact into consideration to improve equity in water supply in the city. The amount of water supplied to any location should correspond to the population in that area.

Water supply between and within DAWASA branches is also unevenly distributed both in current period and over time. The within branch and district inequality is more pronounced than the between branch and districts. Over time these figures show very minor fluctuations. The between branch and district inequality will remain as long as the design and the pipe layout remain intact. There is a need therefore to overhaul the system and redesign a system that will take into consideration the population dynamics. The within district/branch could be partially attributed to the fact that the supply is already so low. Under such circumstances individuals in high income groups will receive what ever little water that is available while the majority mostly the low income individuals will go without in which case they will obtain their supplies from the less safe sources. The time spent to search for water, the safety of those sources, the costs involved in treating the water to make it safe for human use and whether or not the population can afford treatment are critical for the well being of the people. Risks for diseases such as cholera, diarrheas etc. are therefore very real for the residents of Dar es

Salaam City. In all cases the poor will be the most affected. The government therefore needs to act fast to alleviate this crisis otherwise the cost of an epidemic outbreak in terms of medicine and life, loss of workdays searching for water, may be overwhelming to the economy.

6.4 The Willingness to Pay for Improved Water Supply and Quality

The results from the WTP estimation show that the sex of the head of the household is not significant in determining WTP for the household. Willingness to pay was shown to increase with the level of the household income. The income elasticity of WTP in this case was 0.6. Younger respondents had a higher WTP than their counterpart – the older respondents. Willingness to pay was also shown to increase with education, indicating the importance of education in creating hygiene awareness. About 92% of the households surveyed reported that they usually boil their water before use for health concerns indicating concerns regarding the city water quality. The WTP figures can be used as approximations for the lower estimate of benefits to consumers from improved water supply and quality improvements.

6.5 The benefits of Increased Potable Water Supply in the City of Dar es Salaam

In this study, a Marshallian partial equilibrium analysis was employed to estimate the benefits of increased water supply for the city of Dar es Salaam in Tanzania. The results show that the net benefit to both consumers and water suppliers is positive. While the need for improvement of the city water supply is clear, the choice between the status quo and its change in terms of who should undertake the water supply function is critical. This choice needs to be made taking into consideration both the short and long term cost implications to the residents of Dar es Salaam and the nation at large. Issues of quality and quality control, equity in distribution as well as efficiency should feature high in such a choice.

6.7 Policy Recommendations

The following are policy recommendations stemming from this study:

1. Equity in water distribution is critical. Water authorities need to consider both current and future populations in different areas in their jurisdiction in their designs and pipe layout to ensure adequate water and pressure at all times. In places where public taps are installed the number of persons per public tap may be a good indicator for equity.
2. Efficiency targets needs to be set in measurable terms and followed. Benchmarking efficiency goals with other comparable cities/towns locally and across borders may also help. Where targets are not met, satisfactory explanations needs to be provided. Incentives for performance and non-performance may also help.
3. The city of Dar es Salaam and the government at large need to look for an alternative supply of water for the city. The government also needs to consider either full privatization or private-public arrangement for improving availability of capital for investment in the city water sector as well as for improved management, equity and efficiency in the city water delivery.

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Appendix 1

Derivation of Consumer and Producer Surpluses with Improved Water Supply

Assumptions

1. Constant price elasticity of demand

2. Constant price elasticity of supply

With these assumptions:

The equilibrium quantity of demand and supply before improvements is given by

$$Q_0 = D_0 = \beta P_0^{-\varepsilon} \tag{1}$$

$$Q_0 = S_0 = \alpha P_0^{\delta} \tag{2}$$

But at equilibrium $D_0 = S_0$

$$\text{i.e. } \beta P_0^{-\varepsilon} = \alpha P_0^{\delta} \tag{3}$$

From equation 3: The equilibrium P_0 is obtained as follows:

$$\frac{P_0^{-\varepsilon}}{P_0^{\delta}} = \frac{\alpha}{\beta}$$

$$\alpha(P_0)^{\varepsilon+\delta} = \beta$$

$$P_0 = \left(\frac{\beta}{\alpha}\right)^{\frac{1}{\varepsilon+\delta}} \tag{4}$$

From equation 2: $Q_0 = \alpha P_0^{\delta}$, substituting P_0, we get the equilibrium Q_0

i.e. $Q_0 = \alpha\left[\left(\frac{\beta}{\alpha}\right)^{\frac{1}{\varepsilon+\delta}}\right]^{\delta}$

$$=\alpha\left[\left(\frac{\beta}{\alpha}\right)^{\frac{\delta}{\varepsilon+\delta}}\right]$$

$$\alpha\beta^{\frac{\delta}{\varepsilon+\delta}}\alpha^{\frac{-\delta}{\varepsilon+\delta}}$$

$$\alpha^{\frac{\varepsilon}{\varepsilon+\delta}}\beta^{\frac{\delta}{\varepsilon+\delta}} \tag{5}$$

Assuming a Z shift in the demand function

i.e. $Z = N + \eta Y$

where: N = the rate of change in total population

η = income elasticity of demand

Y = the proportional change in per capita income

The new demand function will be:

$$Q = \beta(1 + Z)P^{-\varepsilon} \tag{6}$$

With the new demand function, the new equilibrium price is derived as follows:

$$Q = \beta(1 + Z)P^{-\varepsilon} = \alpha P^{\delta} \tag{7}$$

(from equations 6 and 2)

$$\frac{\beta(1+Z)}{P^{\varepsilon}} = P^{\varepsilon+\delta}$$

$$P = \left[\frac{\beta(1 + Z)}{\alpha}\right]^{\frac{1}{\varepsilon+\delta}}$$

$$= [\beta(1 + Z)]^{\frac{1}{\varepsilon+\delta}} \alpha^{\frac{-1}{\varepsilon+\delta}}$$

$$= \beta^{\frac{1}{\varepsilon+\delta}} (1 + Z)^{\frac{1}{\varepsilon+\delta}} \alpha^{\frac{-1}{\varepsilon+\delta}}$$

$$= \left(\frac{\beta}{\alpha}\right)^{\frac{1}{\varepsilon+\delta}} (1 + Z)^{\frac{1}{\varepsilon+\delta}}$$

But $\left(\frac{\beta}{\alpha}\right)^{\frac{1}{\varepsilon+\delta}} = P_0$ (from equation 4)

Hence: $P_1 = P_0 (1 + Z)^{\frac{1}{\varepsilon+\delta}}$ (7)

Substituting P_1 into equation 2; the new equilibrium Q_1 is derived as follows:

$$Q_1 = \alpha\left[P_0 (1 + Z)^{\frac{1}{\varepsilon+\delta}}\right]^{\delta}$$

Since $P_0 = \left(\frac{\beta}{\alpha}\right)^{\frac{1}{\varepsilon+\delta}}$

$$Q_1 = \alpha\left(\frac{\beta}{\alpha}\right)^{\frac{\delta}{\varepsilon+\delta}} (1 + Z)^{\frac{\delta}{\varepsilon+\delta}}$$

$$= \alpha\alpha^{\frac{-\delta}{\varepsilon+\delta}} \beta^{\frac{\delta}{\varepsilon+\delta}} (1 + Z)^{\frac{\delta}{\varepsilon+\delta}}$$

$$= \alpha^{\frac{\varepsilon}{\varepsilon+\delta}} \beta^{\frac{\delta}{\varepsilon+\delta}} (1 + Z)^{\frac{\delta}{\varepsilon+\delta}}$$

$$= Q_0 (1 + Z)^{\frac{\delta}{\varepsilon + \delta}} \qquad (8)$$

(from equation 5)

The Total, Consumer and Producer Surpluses

Total Surplus is made up of the Consumer Surplus (CS) and Producer Surplus (PS). As such: $\Delta TS = \Delta CS + \Delta PS$

The change in Consumer Surplus is given as:

$$\Delta CS = \left\{ \int_{g_0}^{Q_1} D_1 \partial q - P_1 (Q_1 - g_0) \right\} - \left\{ \int_{g_0}^{Q_0} D_0 \partial q - P_0 (Q_0 - g_0) \right\} \qquad (9)$$

where: D_0 and D_1 are the current and future demands, Q_0 and Q_1 are current and future water supplies respectively.

Now, let $\lambda = \dfrac{Q - g_0}{Q}$

i.e. ratio of water sold by private suppliers

$$g_0 = Q_0 (1 - \lambda_0) \text{ and } Q_1 (1 - \lambda_1)$$

i.e. government water supply at the initial and future time periods

Substituting g_0 into equation 9 we get:

$$\Delta CS = \left\{ \int_{g_0}^{Q_1} D_1 \partial q - P_1 (Q_1 - Q_1 (1 - \lambda_1)) \right\} - \left\{ \int_{g_0}^{Q_0} D_0 \partial q - P_0 (Q_0 - Q_0 (1 - \lambda_0)) \right\} \qquad (10)$$

Rearranging terms:

$$\Delta CS = \int_{g_0}^{Q_1} D_1 \partial q - \int_{g_0}^{Q_0} D_0 \partial q - P_1 Q_1 + P_1 Q_1 (1-\lambda_1) + P_0 Q_0 - P_0 Q_0 (1-\lambda_0)$$

$$= \int_{g_0}^{Q_1} D_1 \partial q - \int_{g_0}^{Q_0} D_0 \partial q - P_1 Q_1 \lambda_1 + P_0 Q_0 \lambda_0 \qquad (11)$$

From equation 6 we know that:

$$Q_1 = \beta (1 + Z) P^{-\varepsilon}$$

Re-arranging:

$$Q_1 P^{\varepsilon} = \beta (1 + Z)$$

$$P^{\varepsilon} = \beta (1 + Z) Q_1^{-1}$$

$$P = [\beta (1 + Z) Q_1^{-1}]^{\frac{1}{\varepsilon}}$$

Similarly;

$$Q_0 = \beta P^{-\varepsilon} \qquad \text{(from equation 1)}$$

$$Q_0 P^{\varepsilon} = \beta$$

$$P^{\varepsilon} = \beta Q_0^{-1}$$

$$P = [\beta Q_0^{-1}]^{\frac{1}{\varepsilon}}$$

Substituting D_1 and D_0 in equation 12 and integrating we get:

$$\Delta CS = \int_{g_0}^{Q_1} (Q_0 P_0^{\varepsilon})^{\frac{1}{\varepsilon}} (1 + Z)^{\frac{1}{\varepsilon}} q_1^{\frac{1}{\varepsilon}} \partial q - \int_{g_0}^{Q_0} (Q_0 P_0^{\varepsilon})^{\frac{1}{\varepsilon}} q_0^{\frac{-1}{\varepsilon}} \partial q - P_1 Q_1 \lambda_1 + P_0 Q_0 \lambda_0$$

(Note: $\beta = Q_0 P_0^{\varepsilon}$ (from equation 1)

$$= Q_0^{\frac{1}{\varepsilon}} P_0 (1+Z)^{\frac{1}{\varepsilon}} \frac{1}{1-\frac{1}{\varepsilon}} q_1^{1-\frac{1}{\varepsilon}} \Bigg|_{g_0}^{Q_1} - Q_0^{\frac{1}{\varepsilon}} P_0 \frac{1}{1-\frac{1}{\varepsilon}} q_0^{1-\frac{1}{\varepsilon}} \Bigg|_{g_0}^{Q_0} - P_1 Q_1 \lambda_1 + P_0 Q_0 \lambda_0$$

$$= Q_0^{\frac{1}{\varepsilon}} P_0 (1+Z)^{\frac{1}{\varepsilon}} \frac{1}{1-\frac{1}{\varepsilon}} Q_1^{1-\frac{1}{\varepsilon}} - Q_0^{\frac{1}{\varepsilon}} P_0 (1+Z)^{\frac{1}{\varepsilon}} \frac{1}{1-\frac{1}{\varepsilon}} g_0$$

$$- Q_0^{\frac{1}{\varepsilon}} P_0 \frac{1}{1-\frac{1}{\varepsilon}} Q_0^{1-\frac{1}{\varepsilon}} - Q_0^{\frac{1}{\varepsilon}} P_0 \frac{1}{1-\frac{1}{\varepsilon}} g_0$$

$$- P_1 Q_1 \lambda_1 + P_0 Q_0 \lambda_0$$

Substituting g_0 for the two time periods we get:

$$\Delta CS = Q_0^{\frac{1}{\varepsilon}} P_0 (1+Z)^{\frac{1}{\varepsilon}} \frac{1}{1-\frac{1}{\varepsilon}} Q_1^{1-\frac{1}{\varepsilon}} - Q_0^{\frac{1}{\varepsilon}} P_0 (1+Z)^{\frac{1}{\varepsilon}} \frac{1}{1-\frac{1}{\varepsilon}} \left(Q_1 (1-\lambda_1)\right)^{1-\frac{1}{\varepsilon}}$$

$$- Q_0^{\frac{1}{\varepsilon}} P_0 \frac{1}{1-\frac{1}{\varepsilon}} Q_0^{1-\frac{1}{\varepsilon}} - Q_0^{\frac{1}{\varepsilon}} P_0 \frac{1}{1-\frac{1}{\varepsilon}} \left(Q_0 (1-\lambda_0)\right)^{1-\frac{1}{\varepsilon}}$$

$$- P_1 Q_1 \lambda_1 + P_0 Q_0 \lambda_0$$

But $P_1 = P_0 (1+Z)^{\frac{1}{\delta+\varepsilon}}$ and $Q_1 = Q_0 (1+Z)^{\frac{\delta}{\varepsilon+\delta}}$

(from equations 7 and 8 respectively)

Buy substitution:

$$\Delta CS = Q_0^{\frac{1}{\varepsilon}} P_0 (1 + Z)^{\frac{1}{\varepsilon}} \frac{1}{1 - \frac{1}{\varepsilon}} \left(Q_0 (1 + Z)^{\frac{\delta}{\varepsilon + \delta}} \right)^{1 - \frac{1}{\varepsilon}}$$

$$- Q_0^{\frac{1}{\varepsilon}} P_0 (1 + Z)^{\frac{1}{\varepsilon}} \frac{1}{1 - \frac{1}{\varepsilon}} \left(Q_0 (1 + Z)^{\frac{\delta}{\varepsilon + \delta}} (1 - \lambda_1) \right)^{1 - \frac{1}{\varepsilon}}$$

$$- Q_0^{\frac{1}{\varepsilon}} P_0 \frac{1}{1 - \frac{1}{\varepsilon}} Q_0^{1 - \frac{1}{\varepsilon}} - Q_0^{\frac{1}{\varepsilon}} P_0 \frac{1}{1 - \frac{1}{\varepsilon}} (Q_0 (1 - \lambda_1))^{1 - \frac{1}{\varepsilon}}$$

$$- P_0 (1 + Z)^{\frac{1}{\delta + \varepsilon}} Q_0 (1 + Z)^{\frac{\delta}{\varepsilon + \delta}} \lambda_1 + P_0 Q_0 \lambda_0$$

$$\Delta CS = Q_0^{\frac{1}{\varepsilon}} Q_0^{\frac{\varepsilon - 1}{\varepsilon}} P_0 (1 + Z)^{\frac{1}{\varepsilon}} \frac{1}{1 - \frac{1}{\varepsilon}} \left[(1 + Z)^{\frac{\delta}{\varepsilon + \delta}} \right]^{1 - \frac{1}{\varepsilon}}$$

$$- Q_0^{\frac{1}{\varepsilon}} Q_0^{\frac{\varepsilon - 1}{\varepsilon}} P_0 (1 + Z)^{\frac{1}{\varepsilon}} \frac{1}{1 - \frac{1}{\varepsilon}} \left[(1 + Z)^{\frac{\delta}{\varepsilon + \delta}} (1 - \lambda_1) \right]^{1 - \frac{1}{\varepsilon}}$$

$$- Q_0^{\frac{1}{\varepsilon}} Q_0^{\frac{\varepsilon - 1}{\varepsilon}} P_0 \frac{1}{1 - \frac{1}{\varepsilon}} - Q_0^{\frac{1}{\varepsilon}} Q_0^{\frac{\varepsilon - 1}{\varepsilon}} P_0 \frac{1}{1 - \frac{1}{\varepsilon}} (1 - \lambda_0)^{1 - \frac{1}{\varepsilon}}$$

$$- P_0 Q_0 (1 + Z)^{\frac{1}{\delta + \varepsilon}} (1 + Z)^{\frac{\delta}{\varepsilon + \delta}} \lambda_1 + P_0 Q_0 \lambda_0$$

$$\Delta CS = P_0 Q_0 (1 + Z)^{\frac{1}{\varepsilon}} \frac{1}{1 - \frac{1}{\varepsilon}} \left[(1 + Z)^{\frac{\delta}{\varepsilon + \delta}} \right]^{1 - \frac{1}{\varepsilon}}$$

$$- P_0 Q_0 (1 + Z)^{\frac{1}{\varepsilon}} \frac{1}{1 - \frac{1}{\varepsilon}} \left[(1 + Z)^{\frac{\delta}{\varepsilon + \delta}} (1 - \lambda_1) \right]^{1 - \frac{1}{\varepsilon}}$$

$$- P_0 Q_0 \frac{1}{1 - \frac{1}{\varepsilon}} - P_0 Q_0 \frac{1}{1 - \frac{1}{\varepsilon}} (1 - \lambda_0)^{1 - \frac{1}{\varepsilon}}$$

$$- P_0 Q_0 (1 + Z)^{\frac{1}{\delta + \varepsilon}} (1 + Z)^{\frac{\delta}{\varepsilon + \delta}} \lambda_1 + P_0 Q_0 \lambda_0$$

$$= P_0 Q_0 \left\{ \frac{1}{1 - \frac{1}{\varepsilon}} \left[(1 + Z)^{\frac{1}{\varepsilon}} (1 + Z)^{1 - \frac{1}{\varepsilon}} (1 + Z)^{\frac{\delta}{\varepsilon + \delta}} - \left((1 + Z)^{\frac{1}{\varepsilon}} (1 + Z)^{1 - \frac{1}{\varepsilon}} (1 + Z)^{\frac{\delta}{\varepsilon + \delta}} (1 - \lambda_1)^{1 - \frac{1}{\varepsilon}} \right) \right. \right.$$

$$\left. \left. - (1 - (1 - \lambda_0)^{1 - \frac{1}{\varepsilon}} \right] - (1 + Z)^{\frac{\delta + 1}{\varepsilon + \delta}} \lambda_1 + \lambda_0 \right\}$$

$$= P_0 Q_0 \left\{ \frac{1}{1 - \frac{1}{\varepsilon}} \left[(1 + Z)(1 + Z)^{\frac{\delta}{\varepsilon + \delta}} - (1 + Z)(1 + Z)^{\frac{\delta}{\varepsilon + \delta}} (1 - \lambda_1)^{1 - \frac{1}{\varepsilon}} \right. \right.$$

$$\left. \left. - (1 - (1 - \lambda_0)^{1 - \frac{1}{\varepsilon}} \right] - (1 + Z)^{\frac{\delta + 1}{\varepsilon + \delta}} \lambda_1 + \lambda_0 \right\}$$

$$= P_0 Q_0 \left\{ \frac{1}{1 - \frac{1}{\varepsilon}} \left[(1 + Z)^{\frac{\delta + 1}{\varepsilon + \delta}} - (1 + Z)^{\frac{\delta + 1}{\varepsilon + \delta}} (1 - \lambda_1)^{1 - \frac{1}{\varepsilon}} \right. \right.$$

$$\left. \left. - (1 - (1 - \lambda_0)^{1 - \frac{1}{\varepsilon}} \right] - (1 + Z)^{\frac{\delta + 1}{\varepsilon + \delta}} \lambda_1 + \lambda_0 \right\}$$

$$\Delta CS = P_0 Q_0 \left\{ \frac{1}{1 - \frac{1}{\varepsilon}} \left[u (1 - (1 - \lambda_1)^{1 - \frac{1}{\varepsilon}}) - (1 - (1 - \lambda_0)^{1 - \frac{1}{\varepsilon}} \right] - u \lambda_1 + \lambda_0 \right\}$$

$$u = (1 + Z)^{\frac{\delta + 1}{\varepsilon + \delta}}$$

$$\Delta CS = P_0 Q_0 \left\{ \frac{1}{v} \left[u (1 - (1 - \lambda_1)^v) - (1 - (1 - \lambda_0)^v \right] - u \lambda_1 + \lambda_0 \right\} \quad (12)$$

$$v = 1 - \frac{1}{\varepsilon}$$
