Evaluation of the Willingness to Pay of Households for a Potable and Reliable Water Supply in Famagusta, North Cyprus

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ABSTRACT

This study is an evaluation of the willingness to pay of households for a potable and reliable water supply in Famagusta, North Cyprus. The averting expenditure method is used to identify consumers' willingness to pay for potable and reliable water. A levelized cost approach along with an economic cost benefit analysis is conducted to find the impact of rehabilitating the currently insufficient water supply system present within the district. North Cyprus has suffered from water supply shortages for most of its existence. The recent Turkish-North Cyprus pipeline project served to remedy the actual supply of water to the nation however, the water distribution network that delivers water to households within North Cyprus provides unpotable water intermittently which forces residents to incur coping costs in order secure water for both drinking and non-drinking purposes.

Famagusta is the ideal district within the country to conduct such an analysis as the water distribution network was rehabilitated due to funding from a prior EU project. In addition, the cost of implementing an elevated central water storage is known and an accurate estimation of benefits of such a project is conducted. The results of the initial analysis at the district level are then extended to the rest of North Cyprus given the similar infrastructure used throughout the country and economic net benefits of improving the water supply system are estimated.

Keywords: willingness to pay, water supply, economic analysis, sensitivity analysis

ÖZ

Bu çalışma, Kuzey Kıbrıs Gazimağusa'da hane halkının içilebilir ve güvenilir su temini için ödeme istekliliğinin bir değerlendirmesidir. Harcamaların önlenmesi yöntemi, tüketicilerin içilebilir ve güvenilir su için ödeme yapma istekliliğini belirlemek için kullanılır. Bölgede halihazırda yetersiz olan su temin sisteminin rehabilite edilmesinin etkisini bulmak için ekonomik maliyet fayda analizi ile birlikte seviyelendirilmiş bir maliyet yaklaşımı yürütülmektedir. Kuzey Kıbrıs, varlığının büyük bir bölümünde su sıkıntısı çekmiştir. Yakın tarihli Türk-Kuzey Kıbrıs boru hattı projesi, ulusun gerçek su arzını düzeltmeye hizmet etti, ancak Kuzey Kıbrıs'taki evlere su sağlayan su dağıtım şebekesi, aralıklı olarak içilemez su sağlıyor ve bu da sakinleri her ikisi için de güvenli su sağlamak için başa çıkma maliyetlerine katlanmak zorunda bırakıyor. içme ve içmeme amaçlı.

Mağusa, daha önceki bir AB projesinden sağlanan fon nedeniyle su dağıtım şebekesi rehabilite edildiğinden, bu tür bir analiz yapmak için ülke içinde ideal bir bölgedir. Ek olarak, yükseltilmiş bir merkezi su deposu uygulamanın maliyeti bilinir ve böyle bir projenin faydalarının doğru bir tahmini yapılır. İlçe düzeyindeki ilk analizin sonuçları, ülke genelinde kullanılan benzer altyapı göz önüne alındığında Kuzey Kıbrıs'ın geri kalanına genişletilir ve su tedarik sisteminin iyileştirilmesinin ekonomik net faydaları tahmin edilir.

Anahtar Kelimeler: ödeme istekliliği, su temini, ekonomik analiz, duyarlılık analizi

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Chapter 1

INTRODUCTION

Cyprus is one of the largest islands in the Mediterranean located to the south of Turkey. It is split between the Turkish Cypriots that reside in the North and the Greek Cypriots in the south. North Cyprus (officially named the Turkish Republic of Northern Cyprus) has a population of approximately 387,000. The two largest sectors of the nation are tourism and higher education with a GDP per capita of 10,055 USD according to the latest statistic provided by the State Planning Organization (2020).

North Cyprus has suffered from scarce water supplies for almost the entirety of its existence. The situation was partially addressed with the completion of the Turkey-North Cyprus pipeline in 2015. The 80-kilometer pipe supplies fresh water to the entirety of North Cyprus. However, the water system of the country still leaves much to be desired. The water that arrives from Turkey is stored in the Geçitköy dam. It is then distributed by the public water utility to households and other facilities throughout the country using a network of leaky pipelines. This results in a water supply that is unpressurized, intermittent and not potable.

In most developing countries, such a water system would not be unexpected. However, given that the GDP per capita of North Cyprus lifts its status above what would be normally categorized as a "developing" country (World Bank); the fact that its population is still dealing with an unpotable and unpressurized water supply is something worth addressing. To cope with the inadequate water supply system, residents of TRNC incur considerable averting expenditures to provide themselves with 24/7 access to pressurized and drinkable water.

The purpose of this thesis is to estimate the willingness to pay (WTP) of households for a reliable and potable water supply by measuring the averting expenditures incurred to deal with the current water system. Once measured, the WTP will be used as a basis upon which an economic analysis of the rehabilitation of the municipal water supply system and the installation of a centralized water storage tank will take place.

Residents of North Cyprus have a keen interest in becoming a part of the European Union. An improved potable water supply to its residents will aid in this endeavor as the new system will be up to par with EU regulations. Once the leaking distribution pipes are replaced and the elevated central water tank is installed in each community, the utility will be able to supply continuous pressurized water throughout its district.

1.1 Background

As mentioned earlier, residents of North Cyprus incur considerable averting expenditures to cope with the current water supply system. These averting expenditures include the installation of water storage tanks of an average size of two cubic meters at ground level and water tanks of an average size of one cubic meter on the rooftop of their buildings (Korman, 2002). Through the storage of water, these two tanks provide continuous water supply for the residents despite the intermittent supply of water coming from the municipality. Along with these two water tanks, a 1 horsepower water pump is installed to move water from the lower water tank to a roof tank. The roof water tank's main function is to provide households with water using gravity, ensuring access to water even in the absence of a supply of electricity. Electricity outages have been a common occurrence in the country therefore this function of the roof water tank is quite essential (Ozbalfi & Jenkins, 2016). From the survey of consumers that has been conducted it was found that a minority of households deem the water pressure that gravity provides from the roof water tank not enough. To rectify this situation, they install a water booster pump next to the roof water tank to increase the water pressure at the expense of an increased electricity bill.

1.2 Northern Cyprus Water Supply Project

The Northern Cyprus Water Supply project was implemented to combat the currently inadequate water supply system using an 80km pipeline that runs under the Mediterranean Sea delivering 75 million cubic meters of water annually to the TRNC. Of the 75 million cubic meters of water, 50.3% will be allocated for household use while the rest will go towards irrigation purposes (General Directorate of State Hydraulic Works, Republic of Turkey).

This project consisted of 4 phases with the initial implementation starting in March 2011 and the third phase completed in December 2016. Phase one details the construction that took place in Turkey, phase two was the construction of the pipeline underwater to North Cyprus with the third and fourth phases being concerned with treating and transporting water to its destination. Phase 3 was the construction of the Guzelyalı pumping station, Geçitköy dam, pumping station and potable water plant. The fourth and last phase of the project has yet to be fully implemented. It involves establishing the main transmission lines from the northern part of the country to the rest of the cities through main transmission lines. Current water distribution lines to final consumers within districts are to be rehabilitated.

The fourth and final phase of the project came to a halt due to the absence of funds. The main transmission lines to each district were established however the water supply networks within each district were largely remained untouched.

The water that is distributed by the municipality is potable, but the current system pollutes the water by the time it reaches the end user's household. The leaking distribution pipes cripple the ability of the network to provide continuous water pressure. The end user is forced to store this water in outdoor tanks that are constantly exposed to the sun. The heat from the sun causes bacteria to grow and chemicals from the plastic tanks to break down in the water making it unsuitable to use for drinking or cooking. This effect is exacerbated even further due to the large amount of sunlight present within North Cyprus year-round.

The only city which had its water distribution pipes replaced was Famagusta due to funding from a prior EU project. Despite the network rehabilitation, the district still cannot provide continuous water pressure to its residents because the current municipal central water storage tank is not located at an adequate level of elevation that would bring about such pressure. If a new central storage tank was installed at a sufficient level of elevation, the newly pressurized water supply would allow residents to get rid of the plastic water tanks and pumps and receive potable water directly from the municipality without the need to store it in plastic tanks exposed to the sun.

1.3 Overview of Study

This study focuses on the city of Famagusta with all the data used gathered locally. Famagusta is the optimal district within North Cyprus to conduct such research since the actual cost of replacing the water distribution pipelines is known. Averting expenditures of residents to cope with the intermittent supply have also been documented historically, in addition to a separate observational survey that was done for the purpose of this study (Korman, 2002). These data grant us the ability to discern the difference between the WTP for a reliable supply of water and the additional value gained when that same water is supplied in a manner that retains its potable characteristic.

Chapter 2

METHODOLOGY

The averting expenditure method evaluates a consumer's willingness to pay through the actions they take to cope with a certain situation (coping costs). Coping costs are initially identified, estimated, and then converted to the levelized cost per cubic meter of water used. In this case, the following averting expenditures (coping costs) presented in Table 1 are incurred by households to deal with the intermittent and unpotable water supply.

Table 1: Averting Actions Taken by the Households

A. Averting expenditures incurred by residents to deal with an unreliable water supply
1. Buy and maintain a water tank of one cubic meter on the rooftop of each household
2. Buy and maintain a water tank of two cubic meters in the ground floor of each household
3. Buy, maintain and operate a water pump of one horse power
4. Buy, maintain and operate a water booster pump for water pressure within the household
B. Averting expenditures incurred by residents for drinking and cooking purposes in the presence of an unpotable water supply
1. Buy bottled water for drinking and cooking purposes
2. Installation of water purification systems

As indicated in Table 1, residents were forced to purchase water tanks, water pumps and water booster pumps when deemed necessary to maintain continuous access to water (Korman, 2002).[1]

[1] In addition to the data obtained Korman, 2002; an observational survey of 331 households was conducted to find the proportion of households with the standard set of apparatus mentioned in Table 1 Part A to deal with the unreliable water supply.

2.1 Survey for Drinking and Cooking Water Expenditures

When it comes to sources of drinking and cooking water, 72.4% of residents purchase bottled water while 27.6% purchased water purification systems.[2] This information was collected through a survey conducted on a sample of the population of Famagusta specifically for this analysis. The survey was able to include simple and straightforward questions due to the basic nature of the data being gathered. The sample population was comprised of adults of various ages as older demographics are much more likely to be aware of their spending habits and would be more familiar with the water system installed within their households. The survey was administered in both English and Turkish and in person in order to ensure that participants correctly understood what was being asked of them and minimize junk data. A total of 214 participants formed the sample population.

Data collected with the survey included the average amount of drinking water consumed per day through various venders, cost of drinking water bottles of different sizes involved in coping with the current water system, cost of equipment obtained as part of averting expenditures (water tanks, pumps, filtration systems, etc.) and the percentage of water filtration systems installed.

In addition to the sampling survey, an observational survey was conducted to find out the types of equipment consumers install in their homes for non-drinking water in as a result of the current water supply. The structure of the observational survey can be found in Appendix B.

[2] A survey was conducted on 214 residents of Famagusta to find out what type of averting actions residents perform to deal with the unpotable water supply (for both drinking and non-drinking purposes. The list of questions can be found in Appendix A.

2.2 Averting Expenditure Method

The household production function theory of consumer behavior acts as the foundation for the averting expenditure method. The theoretical framework of the averting expenditure method is documented by Cook et al. (2016), Pattanyak et el. (2005), Wu and Huang (2001) and Abrahams et al. (2000).

The averting expenditure method utilizes the averting behavior residents choose to undergo to find a way around the negative outcomes of a situation that they cannot solve by themselves. In this case, we are measuring the averting behavior of residents coping with an insufficient municipal water supply with the intention of improving both the quality and availability of water for consumption purposes. The averting behaviors chosen include purchasing products that provide a method to store water, purchasing bottled potable water from vendors and installing water filtration systems to purify the water supplied by the municipality.

These goods purchased act as substitutes in the pursuit of an improved service and divulges the consumer’s willingness to pay for a potable municipal water supply (Korman, 2002).

When estimating the consumer’s WTP using averting expenditures, it must be stated that this method results in a lower bound estimate of the actual WTP of consumers for an improved water supply. The averting expenditure method underestimates the actual benefits from improving the water supply as the disutility (discomfort) of an unpotable and intermittent water supply is not considered and is still present despite averting actions taken by residents (Korman, 2002; Nirmala, 2014; Wu & Huang, 2011).

2.3 Levelized Cost Approach

The levelized cost approach utilizes all capital and operating costs of an investment over their respective lifespans (Cooley & Phurisamba, 2016). The price of the levelized cost of water (LCW) is constant (in real terms) and it is found by equalizing the net present value of the lifecycle cost of averting expenditures to the net present value of lifetime water consumption. The levelized cost of water (LCW) is communicated as per 1 cubic meter of water consumed. Equation 1 is utilized to calculate the levelized cost of water. Table 2 summarizes the variables denoted within equation 1 and equation 2 below.

$$LCW = \frac{\sum_{n=0}^{N} \frac{C_n + O_n + M_n}{(1+r)^n}}{\sum_{n=0}^{N} \frac{q_n}{(1+r)^n}} \qquad (1)$$

Table 2: Parameters of Equation 1 and 2

$\boldsymbol{n}$	n^{th} year lifecycle
$\boldsymbol{N}$	Lifetime of Analysis
$\boldsymbol{q_n}$	Annual water consumption in year *n*
$\boldsymbol{C_n}$	Annualized capital cost in year *n*
$\boldsymbol{M_n}$	Maintenance cost in year *n*
$\boldsymbol{r}$	Real discount rate
$\boldsymbol{t}$	Lifetime of Capital

q_n denotes the annual water consumption, C_n is the annualized capital cost in year *n*, O_n is the operating cost in year *n*, M_n is the maintenance cost in year *n*, *r* is the real discount rate, *n* represents *n* year lifecycle and *N* represents the lifetime of the analysis.

The annualized capital cost, C_n is determined by multiplying the total capital cost by a capital recovery factor (CRF). The CRF is used to find the present value of an annuity and is equal to an amortization factor used in financial analysis where:

$$CRF = \frac{r * (1 + r)^t}{(1 + r)^t - 1} \; ; \; t = lifetime\ of\ the\ capital, \;\; r = real\ discount\ rate \quad (2)$$

2.4 Investment Appraisal

This study is done using the Investment Appraisal framework to forecast the outcomes of both the presence and absence of an intervention to remediate the current water supply system. A Cost-Benefit Analysis (CBA) usually involves multiple types of analyses. Due to the nature of this case, only an economic analysis along with a sensitivity analysis is required. The willingness to pay of consumers is considered an economic metric. Since it is the central focus of this study, a prior financial analysis is unnecessary (a financial analysis of the centralized water storage tank can be performed elsewhere if needed). Once the economic analysis is complete, a sensitivity analysis is conducted to measure changes in costs and benefits based on variability of independent variables. The following sections explain each type of analysis.

2.4.1 Economic Analysis

An economic analysis differs from a standard financial analysis in that it aims to identify and quantify the impact of a project on the well-being of the society as a whole. The goal is to see whether the net benefit of society increases or decreases as a result of project implementation. Economic appraisal is based on three postulates that act as the foundation of welfare economics.

1. The competitive demand price for an incremental unit of a good measures the economic value to the demander, and hence, its economic benefits.

2. The competitive supply price for an incremental unit of a good measures its economic resource cost.
3. Costs and benefits are added up with no regard to who the gainers and losers are (Jenkins, Kuo, & Harberger, 2014).

An economic cash flow is created by calculating the economic benefits and costs of a project. If a financial analysis is present, the prices and values used in the financial analysis must be first multiplied by conversion factors and transformed into economic prices before they can be utilized in an economic analysis. Conversion factors are a ratio of financial to economic value. They serve to factor in benefits or costs that are not usually represented on a project's financial balance sheet. If the economic value of a variable is higher than its financial value then the conversion factor is greater than 1, if the opposite is true then the conversion factor is less than 1.

An economic analysis involves building a "with project" and "without project" case. These two cases are compared in order to obtain the incremental economic cash flow from which the Economic Net Present Value (ENPV) is calculated. A positive ENPV indicates that the project is beneficial from a societal standpoint. Public entities such as governments and non-profit organizations are much more likely to accept projects with positive ENPVs.

2.4.2 Sensitivity Analysis

Most Projects are built with the intention of having them operate for decades. When the future is involved, not everything goes according to plan and uncertainties need to be considered. A sensitivity analysis is crucial in that it provides insight into the risks involved in a project which allows parties involved to create strategies to mitigate such risks. This type of analysis is carried out by choosing independent variables that are deemed to have a significant impact on the project outcome and then adjusting the values of those variables to a realistically possible degree. Metrics such as the ENPV and Benefit-Cost Ratio are then recalculated multiple times after each adjustment, providing insight into possible future scenarios.

2.5 Literature Review

A number of studies examined major water supply policies of North Cyprus that are directly linked with its utilities. Each study evaluated the cost-effectiveness of various forms of interventions that would overcome the water shortage. Göcekuş et al. (2002) researched the issue at hand and recommended an integrated water management approach that would maximize the efficiency of the water at hand. Bicak and Jenkins (1999) and Bicak et al. (2000) performed feasibility studies on water transportation projects from Turkey and the establishment of desalination plants.

Korman (2002) utilized the averting expenditure method in addition to the contingent valuation method in the estimation of the willingness to pay for a potable water supply within Famagusta. This study concluded that the average WTP for a continuous supply of water was between a lower bound estimate of $2.67 (39.84TL) and an upper bound estimate of $3.49 (50.43 TL) when converted to price levels per cubic meter of water in 2022.[3]

The water shortage issue that was present within North Cyprus during the estimation of the WTP of residents for a potable water supply in the Korman 2002 study was more prevalent that it is today. As of 2022, there are a few major differences between now and the beginning of the 21st century, namely the implementation of the Turkey-North

[3] On average, 1 USD= 14.84 TL as of June 2022.

Cyprus Pipeline; subsidization of the water supplied by the municipality and the drastic increase in the income per capita of the country. These differences serve as a sufficient basis to estimate the WTP for a continuous and potable water supply in present circumstances.

In estimating the WTP for access to safe drinking water, studies have been conducted using the averting expenditure method. Amongst those studies are Coo et al. (2016) in Kenya, Nirmala (2014) and Majumdar and Gupta (2009) in India; Pattanayak et al. (2005) in Nepal; Um et al. (2002) in Korea; Abrahams et al. (2000) in Georgia; Mconnell and Rosado (2000) in Brazil and Abdalla et al. (1992) in Pennsylvania, USA.

What differentiates this research from previous endeavors is that the averting expenditures of households will be compared with the cost of establishing a program that would enhance the current water distribution system in addition to estimating the willingness to pay of residents for a reliable water supply. In other words, this study will estimate the net economic benefit of upgrading the water distribution system of the district it is conducted within.

Chapter 3

DATA AND ASSUMPTIONS

Monetary values are all expressed in March 2022 price levels. A real discount rate is used to discount projected cash flows for consistency purposes. The real discount rate is 8% for North Cyprus.

3.1 Averting Expenditures

An observational survey was conducted for the purpose of this study to determine standard forms of averting expenditures amongst households. Over 330 households were used as a sample which included both apartments and standalone household units within the city of Famagusta from various areas within the district. It is found that 92.15% of households incur averting expenditures that include a $2m^3$ water tank on the ground level, a $1m^3$ water tank on the roof, a water pump to move the municipal water into the roof tank, water level sensors in each tank, tank beds, pipes to connect the water tanks to the system (Case A). Within Case A, 5.14% of households also purchase a water booster pump and install it next to the tank on the roof for water pressure within the house (Case A-i). In 7.85% of cases (outside of Case A), only a water booster pump along with a hydrofoil and a 2 cubic meter water tank is installed on the ground floor (Case B). This relatively new setup that exists in some modern construction projects reduces initial capital expenditures and relieves the need to install anything on the roof as the water booster pump makes up for the lack of pressure. The downside to this newer type of averting behavior is having to deal with electricity reliability.

3.2 Total Current and New Population

Prior to estimating the WTP of residents, the total coping costs per capita must be estimated. This entails finding the population of Famagusta per year throughout the time duration of the analysis. The statistics provided by the Famagusta water municipality included data on the number households in Famagusta, average number of residents per household and the annual growth of households up to 2021. The current population of the district is then estimated using the given data. The projection of the population for future years is done using the initial data provided by the municipality. The population of Famagusta as of June 2022 is estimated to be 59,300.

Future residents of Famagusta will also engage in averting behaviors to cope with the intermittent water supply. Recent statistics estimate an increase of 1130 individuals per year in the population of Famagusta. This estimate was found by calculating the average population growth per year using the annual population of Famagusta of the last few years provided by the Famagusta Municipality. This increase per year will be used throughout the lifetime of the analysis.

Capital and operating costs per capita are estimated by first calculating the average respective costs of a household then dividing the results by the average household size.

3.3 Water Consumption of Residents of Famagusta

The average amount of water consumed per capita annually is a core data piece when it comes to the estimation of consumer's WTP for an improved potable water supply. It is first used to estimate the average annual operating costs per capita of the current water system post averting expenditures. Information provided by the Famagusta municipal water department acts as a basis upon which the annual and monthly per capita non-drinking water consumption figures can be calculated. In 2022, the average non-drinking water consumption per capita is 61.2 cubic meters per annum and 5.1 cubic meters per month.

Drinking water is obtained either through vendors selling bottled water or through the installation of water filtration systems that purify the municipal water supply that arrives at households. Water filtration system capital and O&M costs will not be used when calculating the cost of potable water obtained through this method, rather it will be equated to the cost of purchasing bottled water from vendors. The cost of purchasing bottled water from vendors is an underestimate of the true cost of water filtration systems. This results in an underestimate of the true value of total coping costs saved once the project is implemented.

Bottled water is mainly obtained through the purchase and refilling of 19-liter water bottles through vendors with a smaller, although considerable percentage of potable water obtained through smaller bottle sizes of 0.5, 1, 1.5 and 5-liter bottles. Drinking water obtained through vendors selling bottled water is not for the sole purpose of coping with the current water supply system. Much of bottled water purchases are made due to convenience. Bottle sizes of 1.5 liter and below will be mainly treated as convenience driven purchases.

Once the new water supply system is implemented, a portion of smaller drinking water bottle purchases will divert to the purchase of reusable flasks that consumers will refill with the now potable water supply from the municipality. The accurate estimation of the elasticity of such a diversion in consumer purchases (from small plastic water bottles to reusable flasks) is outside the scope of this study and therefore will be excluded however, the fact that such a diversion will take place results in an underestimation of benefits of the project within this analysis. Through the survey conducted for the purpose of this study, it is found that the average amount of daily drinking water consumption per capita (for both drinking and cooking purposes) obtained through aforementioned sources is equal to 2.67 liters.

3.4 Expected Lifetime of Capital and the Analysis

The apparatus acquired because of averting expenditures of consumers and the municipal central water storage tank each have a certain average lifetime. The averting expenditure apparatus include water tanks and pipes that are estimated to have an average lifetime of 20 years with water pumps and water booster pumps having a lifespan of 5 years. The municipal central water storage tank is expected to last for 40 years. The analysis will be conducted over a length of 40 years in according with the initial project’s usable life. Once the 40 years pass, the central water tank would either require augmentation or replacement with a possibly larger tank depending on the needs of the district in the future.

3.5 Capital and Maintenance Costs

For this analysis, all suppliers in Famagusta of water tanks, pumps, water booster pumps, and various other pieces of averting expenditure equipment were surveyed in order to obtain the average capital and maintenance costs of said equipment.

There are a few distinctions between current households within Famagusta and households that will come into existence during the time period in which the analysis is conducted. Some averting expenditures are only incurred by new households in order to initially install the equipment purchased when averting behavior takes place. Equipment such as a float for the tank, a check valve and cutoff device for the water connection are factored into both capital and maintenance costs in the case of new households but only the cost of replacing these miscellaneous parts is considered for current households and is only factored into their maintenance costs as current households already own such items. This creates a discrepancy in capital costs between current and new households that is taken into account during the analysis. This discrepancy between current and new households is separate from the differences in costs between Cases A, Ai and B. In addition, our observational survey indicates that only 13% of households utilize a water booster pump and a hydrofoil to deal with water pressure that is deemed inadequate (the 13% of households that utilize a water booster pump are split between Case Ai and Case B). The percentage of water booster pump and hydrofoil installations is important since the pump is active whenever water is being consumed within a household, significantly increasing electricity consumption in tandem.

Cases A, Ai and B have differing capital and maintenance costs due to the different types of averting behaviors. Case Ai has the highest capital and maintenance costs since all equipment previously outlined that is used to cope with the existing water supply is purchased. Case A eliminates the purchase of a water booster pump placing itself in the middle of both cases. Case B removes the purchase of a water pump and a 1 cubic meter water storage tank reducing its capital and maintenance costs to the lowest of the three.

The annual maintenance costs of each tank and water pump includes labor costs, periodic cleaning costs as well as the maintenance of more obscure parts such as the buoy and check valves. This does not mean that maintenance is performed annually on equipment. Rather, the sporadic maintenance cost is spread out as average annual payments despite it only occurring usually every few years.

When it comes to water booster pumps, only detached houses or apartments that are located on the upper floors of buildings may need a water booster pump as gravity may not provide sufficient water pressure for usage. Households that have a gas heater installed also require a water booster pump to be installed to apply enough water pressure into the gas heaters. Despite inadequate pressure being a common issue for a significant portion of residents, the percentage of households with water booster pumps is low at 13% as stated earlier. It is worthy to note that many houses and apartments in the observational survey that were likely suffering from inadequate water pressure did not have water booster pumps. This could be attributed to the high cost of electricity within North Cyprus (Cyprus Turkish Electricity Authority, Kib-Tek). By not using a water booster pump, residents can significantly reduce their monthly electricity bills. Residents may either not see the lower water pressure as an issue or would rather deal with it than pay more in electricity bills.

Table 3: Capital and Maintenance Costs of Households (Constant 2022 TL prices)

A. Capital Costs	
Cost of the water tank of one cubic meter incl. labor cost	2615
Cost of the water tank of two cubic meters incl. labor cost	4047
Cost of the water pump incl. labor cost	1740
Cost of the water booster pump & hydrofoil incl. labor cost	2231
Cost of the pipes incl. labor cost	500
Cost of the total additional equipment for new households	480
B. Maintenance Costs	
Annual maintenance cost of each tank	150
Annual maintenance cost of the water pump	83

These values will be divided by the average number of residents per household of 2.41 provided by the Famagusta Municipal Water Department when calculating annualized capital and maintenance costs per capita.

3.6 Operating Costs

Operating costs are based upon the cost of electricity that is needed to power the water pump and if present, the water booster pump installed in a residence to move water into tanks and water taps. In the previous section dealing with capital and maintenance costs, the household unit is the main focus and will be subsequently divided by the average number of residents to obtain per capita figures since multiple individuals on average occupy the same household that utilizes only one standard set of equipment. While the same scenario is present in operating costs, the need to calculate household operating costs prior to per capita values is removed due to the availability of the average monthly amount of non-drinking water consumption per capita of 5.1 m^3 (Famagusta Municipal Water Department, 2022). As stated before, households with water booster pumps for increased water pressure have operating costs that are significantly higher than those without water booster pumps and only water pumps.

A water pump of one horse power is estimated to take 15 minutes to pump one cubic meter of water from the ground level water tank to the tank on the roof (Korman, 2002). To estimate the cost of electricity incurred when operating the water booster pump, a standardized six-minute shower time per individual is used (Sezai et al., 2005). The water booster pump is also activated whenever any form of washing takes place or when a toilet is flushed. The operation duration of the water booster pump is estimated to be 15 minutes per person per day.

The current price of electricity in North Cyprus including a 10% VAT is 2.7 TL/kWh (0.18 USD/kWh) (Cyprus Turkish Electricity Authority, Kib-Tek). This will be used as the real price of electricity over the 40-year duration of the analysis.

An important distinction to make between a water pump and a water booster pump is that even though they pump the same water supply, the amount pumped per minute by each type of pump is much different. The amount of water pumped per second through outlets into water tanks by water pumps is higher than the amount of water pumped by water booster pumps through taps into households, leading to much shorter operation times from water pumps as gravity is utilized to bring water into homes. Water booster pumps need to operate every time a tap within a household is opened and continues to operate until the tap is closed. The same amount of horsepower is present in both water pumps and water booster pumps and therefore the same amount of electricity is consumed per minute of operation, regardless of the amount of water that was pumped. Modern plumbing involves the use of bathroom and kitchen faucets, shower heads, toilets, washing machines, etc.

These standard household water outlets only allow a limited amount of water to pass through per minute as opposed to outlets leading into water storage tanks which allow much higher amounts of water to pass through within the same time period. In Case A, household water outlets are supplied with water through gravity, removing the need of the water pump and electricity. In Case B, all household water outlets will require the operation of the water booster pump, leading to higher amounts of electricity consumption and hence higher amounts of coping costs.

Table 4: Averting Expenditures in Total Annualized Coping Costs Per Capita (Constant 2022 TL prices)

Current Population	
Case A (with a WP but without a WBP)	611
Case Ai (with a WP and a WBP)	1061
Case B (with a WBP but without a WP)	661
New Population	
Case A (with a WP but without a WBP)	631
Case Ai (with a WP and a WBP)	1081
Case B (with a WBP but without a WP)	671

Total annualized coping costs per capita include both annualized capital costs and annualized O&M costs per capita. Total annual coping costs of Case B (with only a water booster pump and ground floor water tank) of averting behavior are slightly higher than Case A (only a water pump and 2 water tanks with one on the roof to utilize gravity). A portion of the population is willing to incur slightly higher averting expenditures over time and deal with an unreliable supply of electricity in order to not sully the roof of their households and free up roof real estate that can be utilized for other purposes. In other words, there is an additional cost present in Case A that is not taken into account.[4] Namely, the occupation of the roofs of households and degradation of the look of the district due to the presence of these roof water tanks and pumps. Items such as the occupation of the roof and ground floor space by water tanks and pumps are not factored into this analysis therefore the results of this study will be in effect, an underestimation of the true value of the benefits of rehabilitating the current municipal water supply system.[5]

[4] Case Ai is not taken into consideration when comparing cases as it involves an expenditure dealing with a separate issue outside of the items being compared and is present only for reader information.
[5] The need to install water tanks and pumps for every household throughout the city ties up real estate that can be used for other purposes and therefore is another coping cost that is incurred to deal with the current intermittent water supply. The implementation of a central municipal water storage tank would eliminate the need to install such apparatus and free up space that was previously used in order to cope. This newly available land is treated as a benefit that would be gained due to project implementation. In

Chapter 4

ESTIMATION AND RESULTS

Estimating the total coping costs of the population of Famagusta and subsequently the levelized coping costs of an unpressurized water supply is preceded by four calculations. First, the annualized capital cost of the equipment per capita is found using the annualized capital cost per household as a basis. Second, the annual operating and maintenance costs per capita are estimated (with maintenance costs following the same methods used to find annualized capital costs per capita). Third, the total coping costs of current households and new households for non-drinking water within Famagusta are found using the results obtained in prior calculations. The final step is calculating the coping costs of the population for drinking water using data obtained from the survey conducted, local prices of bottled water from vendors and cost of water purification equipment.

Once total coping costs are estimated, the WTP for a reliable water supply in terms of levelized coping costs that consumers incur in the presence of the existing water supply is calculated. The analysis is then expanded and the net social benefit of rehabilitation of the water distribution system of Famagusta (including the installment of a central water storage tank) is measured.

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addition, the unsightly nature of having water tanks and pumps plastered throughout the city is also a cost that would be gained as a benefit as well in the "with project" scenario.

4.1 Annualized Capital Cost of Capital Equipment

The annualized capital cost (ACC) of the capital equipment is a key metric in evaluating the annual coping costs of the population. Estimating the ACC requires finding the capital recovery factors (CRFs) of each type of capital equipment by utilizing equation (2) presented in a previous section. The relevant CRF of each capital equipment is thereafter multiplied by the respective capital investment cost. For this step in the analysis, we must once more find the annualized capital costs per household prior to finding the ACC per capita (each household uses one set of equipment). Table 5 contains the results of the method outlined for current and new residents.

Table 5: Annualized Capital Cost of the Capital Equipment per capita (Constant 2022 TL prices)

	$1m^3$ Water tank	$2m^3$ Water tank	Water pumps	Water booster pumps & Hydrofoil	Total (Case A-Ai)	Total (Case B)
CRF	0.102	0.102	0.250	0.250		
Current Population						
Capital Costs[c]	3,551[a]	4,997[a]	1740	2231		
ACC per capita	150	211	181	232	542-773[d]	443
New Population						
Capital Costs[c]	3,791[a]	5,237[a]	680[b]	400		
ACC per capita	160	221	181	232	562-794[d]	453

[a]Cost of the piping and tank beds are included in the cost of the water tanks since their lifetimes are same and they all will need to be replaced at the same time.

[b]Additional equipment cost is included in the cost of the water pump when we estimate ACC of the water pump for new households.

[c]Capital Costs are presented per household for conceptualization purposes (One set of equipment per household). These figures are divided by the average number of residents per household before the ACC per capita is calculated.

[d]The lower end of ACC per capita is Case A (without a water booster pump) and the upper end is Case Ai (with a water booster pump).

As presented in Table 5, the ACC of capital equipment per capita for current residents is estimated to be 542 TL for Case A of averting behavior and 773 TL for Case Ai.

Case B has an ACC of capital equipment per capita of 443 TL. The ACC per capita for new residents is estimated to be 562 TL for Case A, 794 TL for Case Ai and 453 TL for Case B.

4.2 Total Coping Costs of Current Population for Non-Drinking Water

Coping costs incurred must be projected over time in the absence of an intervention. They include the operating and maintenance (O&M) costs along with the cost of replacing capital items at the end of their respective lifespans.

4.2.1 Total Annualized Capital Costs of Current Population

Current residents of Famagusta previously invested in capital items required to cope with the existing water system. These investments will require replacement overtime without an intervention. The assumption is that these capital items were acquired in equal proportions over past lifetimes of the same assets. Therefore, fixed proportions of these assets are going to be replaced periodically throughout the analysis. The annual incremental capital costs stem from the cost of replacing these items in a "without project" ("without intervention") scenario. Total Capital Cost Estimates of current population is presented in Table 6.

Table 6: Total Capital Costs of Current Population (Constant 2022 TL prices)

	Year 1	Year 5	Year 10	Year 20 - 40
(1) Total Capital Cost of Water Tanks of 2 cubic meters with pipes	625,679	3,128,394	6,256,788	12,513,575
(2) Total Capital Cost of Water Tanks of 1 cubic meter with pipes	409,667	2,048,337	4,096,674	8,193,349
(3) Total capital cost of the water pumps	1,974,761	9,873,803	9,873,803	9,873,803

(4) Total capital cost of the water booster pumps & hydrofoils	357,020	1,785,099	1,785,099	1,785,099
(5) Total capital costs of current households	3,367,127	16,835,633	22,012,364	32,365,826
(6) PV of total capital costs @8%	263,837,248			

The total annualized capital costs of water tanks increased in fixed proportions per year with new purchases being made up to year 20 after which ACC remains until year 40.

Every year an estimated twentieth of all current residents will replace their water tanks in a given year (given that the average lifespan of a water tank is 20 years). Once 20 years have passed since the beginning of the project's implementation, current residents will incur the same amount of ACC each year throughout the rest of the analysis. Total annual capital costs of water pumps and water booster pumps & hydrofoils of current residents are estimated using the same method.

Using the approach explained above, capital costs of existing water tanks, pumps and other apparatus that are purchased prior to the project are treated as sunk costs. Only the costs of asset replacement over time are treated as economic costs in the "without project" scenario. The present value of capital costs incurred when averting behavior takes place is estimated to be at 263,837,248 TL (17,778,790 USD) over 40 years.

4.2.2 Total Operating and Maintenance Costs of Current Population

Operating & maintenance costs per capita and hence total operating & maintenance costs for the current population depends on whether a water booster pump & hydrofoil (these items together will be called a water booster pump) are installed and used in a residence. The percentage of households with a water booster pump of 13% is taken into account when performing calculations (Both Cases Ai and B). Operating costs per capita estimates are presented in Table 7 with maintenance costs per capita in Table 8.

Table 7: Annual Operating Costs per Capita (Constant 2022 TL Prices)

Operating costs without a water booster pump (only a water pump)	
(1) Daily water consumption per capita (m^3)	0.17
(2) Approximately refill time of the water in the roof tank (days) [0.9/(1)]	5.3
(3) Annual operating hour of the pump (hours) [(365/ (2))*0.25]	17.2
(4) Annual electricity cost of the pump (TL) [(3)*0.746 kw*2.7 TL/kWh]	34.7
Operating costs with a water booster pump	
(5) Daily working time of the water booster pump (hour)	0.25
(6) Annual working hours of the water booster pump (hours) [365*(5)]	91.3
(7) Annual electricity cost of the pump (TL) [(6)*0.746 kw*2.7 TL/kWh]	183.7

Table 8: Annual Maintenance Costs per Capita (Constant 2022 TL Prices)

Annual Maintenance Costs without a water booster pump	
Annual Maintenance Cost of Water Tanks	124
Annual Maintenance Cost of Water Pump	35
Total Annual Maintenance Costs per capita	159
Annual Maintenance Costs with a water booster pump	
Annual Maintenance Cost of Water Tanks	124

Annual Maintenance Cost of Water Pump	35
Annual Maintenance Cost of Water Booster Pump	35
Total Annual Maintenance Costs per capita	194

From Table 7, we can see that the annual operating cost per capita without a water booster pump is 35 TL and is increased to 184 TL in the presence of a water booster pump. Table 8 shows that the annual maintenance cost per capita is 159 TL and is increased to 193 TL with a water booster pump. These values are not based on the different cases of averting behavior (Cases A, Ai and B), rather they are simply how much each item would cost to operate on their own. These values are then used to calculate the operating costs of each case and subsequently the total operating and maintenance costs of the population.

The total annual O&M costs of the current population of Famagusta are estimated using per capita values as a basis with the following formula:

$$TOMC = \sum[n * \pi_{wpb} * \left(MC_{wpb} + OC_{wpb}\right) + n * \pi_{wb} * (MC_{wb} + OC_{wb}) + n * (1 - \pi) * (MC_{wob} + OC_{wob})] \tag{3}$$

Table 9: Parameters for Equation 3

$\boldsymbol{n}$	Current population
$\boldsymbol{\pi}$	Total share of households that have a water booster pump
$\boldsymbol{\pi_{wpb}}$	Share of households with both a water pump and water booster pump (Case Ai)
$\boldsymbol{\pi_{wb}}$	Share of households with only a water booster pump and no water pump (Case B)
$\boldsymbol{MC_{wpb}}$	Annual maintenance cost per capita with both a water pump and a water booster pump
$\boldsymbol{MC_{wb}}$	Annual maintenance cost per capita with only a water booster pump

$\boldsymbol{MC_{wob}}$	Annual maintenance cost per capita without a water booster pump and only a water pump (Case A)
$\boldsymbol{OC_{wpb}}$	Annual operating cost per capita with both a water pump and a water booster pump
$\boldsymbol{OC_{wb}}$	Annual operating cost per capita with a water booster pump
$\boldsymbol{OC_{wob}}$	Annual operating cost per capita without a water booster pump and only a water pump

where n is the current population, π is the total share of households that have a water booster pump, π_{wpb} is the share of households with both a water pump and water booster pump (Case Ai), π_{wb} is the share of households with only a water booster pump and no water pump (Case B), MC_{wpb} is the annual maintenance cost per capita with both a water pump and a water booster pump, MC_{wb} is the annual maintenance cost per capita with only a water booster pump, MC_{wob} is the annual maintenance cost per capita without a water booster pump and only a water pump, OC_{wpb} is the annual operating cost per capita with both a water pump and a water booster pump, OC_{wb} is the annual operating cost per capita with a water booster pump and OC_{wob} is the annual operating cost per capita without a water booster pump and only a water pump. Table 10 presents a summary of the total annual O&M costs of the current population.

Table 10: Total Annual O&M Costs of Current Population (Constant 2022 TL prices)

(1) Total O&M cost without a water booster pump and only a water pump (Case A)	9,991,061
(2) Total O&M cost with both a water pump and a water booster pump (Case Ai)	1,254,507
(3) Total Annual O&M Costs with only a Water Booster Pump (Case B)	1,757,016
(4) Total O&M cost of current population	13,002,584
(5) PV of total O&M costs @8%	167,454,847

The total annual O&M costs of the current population of Famagusta are estimated to be 13,002,584 TL (876,185 USD) throughout the next 40 years with the present value of all those years being 139,868,219 TL (9,425,082 USD). The total coping costs of the current population of Famagusta is summarized in Table 11.

Table 11: Total Coping Costs of Current Population for Non-Drinking Water (Constant 2022 TL prices)

	Year 1	Year 10	Year 20	Year 30	Year 40
(1) Total capital costs of current population	3,367,127	22,012,364	32,365,826	32,365,826	32,365,826
(2) Total O&M costs of all cases (A, Ai, B)	13,002,584	13,002,584	13,002,584	13,002,584	13,002,584
(3) Total coping costs of current population (TL)	16,369,710	35,014,948	45,368,410	45,368,410	45,368,410
(4) PV of total coping costs @8%	431,292,094				

4.3 Total Coping Costs of New Population for Non-Drinking Water

Coping costs of new residents is estimated using a forecasted percentage increase in population per year. The total increase in population throughout the duration of the analysis is then factored into calculation methods outlined in previous sections. The percentage of water booster pump users is held the same as the current population for the increases in population (new population) at 13%. All calculation methods outlined in previous sections are utilized to find coping costs of the new residents of Famagusta. Total annual coping costs ($TACC_t$) of new households are estimated using the following formula with Table 12 explaining each variable:

$$TACC_t = n * t * \left[\pi_{wtt} * ACC_{wtt} + (1 - \pi_{wtt}) * ACC_{wt} + \pi_{wp} * ACC_{wp} + \pi_{wpb} * ACC_{wpb} + \pi_{wb} * ACC_{wb} + \pi_{wp} * OC_{wp} + \pi_{wpb} * OC_{wpb} + \pi_{wb} * OC_{wb} + MC_{wp} + MC_{wpb} + MC_{wb}\right] \quad (4)$$

Table 12: Parameters for Equation 4

$\boldsymbol{n}$	Increase in population per year
$\boldsymbol{t}$	Number of year lifecycle
$\boldsymbol{\pi_{wtt}}$	Share of residents with both a 1 cubic meter and 2 cubic meter water tank
$\boldsymbol{ACC_{wtt}}$	Annualized capital cost of both a 1 cubic meter and 2 cubic meter water tank
$\boldsymbol{ACC_{wt}}$	Annualized capital cost of only a 2 cubic meter water tank (Case B)
$\boldsymbol{\pi_{wp}}$	Share of residents with only a water pump
$\boldsymbol{\pi_{wpb}}$	Share of residents with both a water pump and water booster pump
$\boldsymbol{\pi_{wb}}$	Share of residents with only a water booster pump and no water pump (Case B)
$\boldsymbol{ACC_{wpb}}$	Annualized capital cost of both a water pump and water booster pump
$\boldsymbol{ACC_{wb}}$	Annualized capital cost of only the water booster pump
$\boldsymbol{ACC_{wp}}$	Annualized capital cost of only the water pump
$\boldsymbol{OC_{wp}}$	Annual operating cost per capita with only a water pump
$\boldsymbol{OC_{wpb}}$	Annual operating cost per capita with both a water pump and a water booster pump
$\boldsymbol{OC_{wb}}$	Annual operating cost per capita with only a water booster pump
$\boldsymbol{MC_{wpb}}$	Annual maintenance cost per capita with both a water pump and a water booster pump
$\boldsymbol{MC_{wb}}$	Annual maintenance cost per capita with only a water booster pump
$\boldsymbol{MC_{wp}}$	Annual maintenance cost per capita without a water booster pump and only a water pump (Case A)

Estimated total coping costs of new residents are presented in Table 13.

Table 13: Total Coping Costs of New Population for Non-Drinking Water (Constant 2022 TL prices)

	Year 1	Year 10	Year 20	Year 30	Year 40
(1) Total capital costs of new population (TL)	638,268	6,382,683	12,765,366	19,148,048	25,530,731
(2) Total O&M costs of all Cases (A, Ai, B)	247,583	2,475,828	4,951,657	7,427,485	9,903,314
(3) Total coping costs of new population (TL)	885,851	8,858,511	17,717,022	26,575,534	35,434,045
(4) PV of total coping costs of new population @8%	131,995,501				

Total coping costs of the new population within the district is estimated to be 638,268 TL in year 1 and will increase in fixed amounts of the same value every year as annual growth rate of population is held constant for the duration of the analysis. In the absence of an intervention and the water supply system continues to exist in its current state, new residents of Famagusta over the next 40 years will suffer a present value of 131,995,501 TL (8,894,576 USD) in coping costs.

4.4 Total Coping Costs of Total Population for Non-Drinking Water

Total coping costs of the entire population for non-drinking water (found by combining the coping costs of the current and new population) over the 40-year period is estimated to have a present value of 563,287,595 TL (37,957,385 USD). In other words, this is the estimated amount that would be expended in order to deal with the existing water system and would be saved (or treated as an economic benefit) if an investment was made to deliver pressurized water to households without interruption.

4.5 Coping Costs of the Population for Drinking Water

All coping costs estimated so far have covered expenditures solely on securing a reliable, continuous supply of non-drinking water by the population. Residents also require access to potable water which (with the current water supply system) is not provided by the municipality. According to our survey, 72.4% of residents purchase bottled water from vendors with almost 27.9% opting to install a water filtration system within their homes for drinking/cooking purposes. The average amount of daily drinking/cooking water consumed per day of 3.9 liters obtained from Korman (2002) includes all forms of drinking water consumption per capita. In other words, both drinking water consumption obtained from vendors for convenience purposes and water obtained as a coping cost is included in the 3.9 liters per day. The survey conducted for this study found that the average amount of drinking water consumed per day per capita that is categorized as a coping cost is 2.67 liters. Including the entire amount of average daily drinking water consumption would result in an overestimation of the benefits of the project once drinking water figures are converted into potable water obtained from the municipality post project implementation. The price of drinking water is found by calculating the average price of potable water per liter that is purchased from vendors to cope with the municipal water supply (some drinking water is purchased for convenience purposes and cannot be including in coping costs). Water filtration systems are installed in a considerable percentage of cases and will also be treated as a coping cost for drinking water. The results of the estimation are summarized in Table 14.

Table 14: Coping Costs of Population for Drinking Water (Constant 2022 TL prices)

	Year 1	Year 10	Year 20	Year 30	Year 40
(1) Total Population	59,298	69,460	80,751	92,041	103,332
(2) Total drinking water consumption of population categorized as a coping cost (cubic meters)	57,725	67,618	77,510	89,601	100,592
(3) Total coping costs of population for drinking water (TL)	67,469,743	79,031,996	91,878,943	104,725,890	117,572,837
(4) PV of total coping costs for drinking water @8% (TL)	1,043,794,457				

As shown in the Table 14, coping costs for drinking water are significantly larger than coping costs for non-drinking water. The levelized cost of drinking water per cubic meter (explained further in section 4.6) is multiples more expensive than the levelized cost of non-drinking water per cubic meter. Water filtration system costs are again equated on a per capita level to drinking water purchased from vendors resulting in an underestimate of coping costs and hence an underestimation of potential benefits in the form of coping costs saved once the project is implemented. The present value of coping costs of the population of Famagusta over the next 40 years is estimated to be 1,043,794,457 TL (70,336,554 USD).

4.6 Levelized Coping Cost of Unreliable Water Supply and the Willingness to Pay for a Reliable and Potable Water Supply

A levelized coping cost is the amount of coping cost incurred to obtain 1 unit of an item in question. In this case it is the amount of coping cost incurred to obtain 1 cubic meter of drinking/non-drinking water. At the time of this study, residents of Famagusta currently pay 8.5 TL/m^3 (0.57 USD/ m^3) for the municipal water supply. All coping costs estimated are in addition to this water tariff as the analysis is done on an incremental basis (the tariff is paid in both "with" and "without intervention" cases therefore should not be included in coping costs). The levelized cost of incremental expenditures (the averting expenditures) is estimated using the present value of total coping costs for both potable and unpotable (drinking and non-drinking) water consumption of the entire population. Table 15 presents the levelized coping costs of the existing unreliable water supply.

Table 15: Levelized Coping Cost of Unreliable Water Supply (Constant 2022 TL prices)

	Year 1	Year 10	Year 20	Year 30	Year 40
(1) Non-drinking water consumption of total population (cubic meters)	3,629,023	4,250,927	4,941,931	5,632,936	6,323,940
(2) Drinking water consumption of total population (cubic meters)	57,725	67,618	78,609	89,601	100,592
(3) Total water consumption of population (cubic meters)	3,686,749	4,318,545	5,020,541	5,722,536	6,424,532
(4) Coping costs of total population for non-drinking water (TL)	17,255,561	43,873,459	63,085,432	71,943,944	80,802,455
(5) Coping costs of total population for drinking water (TL)	67,469,743	79,031,996	91,878,943	104,725,890	117,572,837
(6) Total coping costs of total population for unreliable water supply (TL)	84,725,305	122,905,455	154,964,375	176,669,834	198,375,292
(7) PV of coping costs of total population for non-drinking water @8% (TL)	563,287,595				

(8) PV of non-drinking water consumption @8% (cubic meters)	56,143,012
(9) Levelized cost of coping costs for non-drinking water (TL/m^3) [(7)/(8)]	10.03
(10) PV of coping costs of households for drinking (potable) water @8% (TL)	1,043,794,457
(11) PV of coping costs of total population for total water consumption @8%(TL) [(7)+(10)]	1,607,082,053
(12) PV of total water consumption @8% (cubic meters)	57,036,055
(13) Levelized value of total coping costs for water (TL/m^3) [(11)/(12)]	28.18

Table 15 shows that the levelized coping cost for non-drinking water is 10.03 TL/m^3 (0.68 USD/m^3) in addition to the tariff charged by the municipality when dealing with the existing inadequate water supply (Table 15/ Row 9). To put it differently, consumers are paying more than just the 8.5 TL/m^3 (0.57 USD/ m^3) charged by the municipality for every cubic meter of non-drinking water consumed. After factoring in the levelized coping cost for potable water, the levelized value of total coping costs for water (for both potable and unpotable) is estimated to be 28.18 TL/m^3 (1.90 USD/m^3).

4.7 Benefits and Costs in Case of Intervention

To summarize the results of the previous sections, the installation of a central water storage tank by the municipality and provision of a pressurized and potable water supply would result in large savings in coping costs in comparison to the costs of the project. Although the water distribution system within Famagusta was rehabilitated prior to the project, it is included in the comparison as its purpose was the improvement of the water supply system as a whole. The cost of this rehabilitation of the system in Famagusta is also used as a basis to calculate the cost of rehabilitation of other parts of North Cyprus. Once a pressurized potable water supply is implemented, a portion of drinking water consumption needs to be removed from benefits to avoid double counting. This portion originates from consumers who were already consuming water from the municipality by filtering it with water filtration systems installed within their own homes.

Table 16: Benefits and Costs in Case of Intervention (Constant 2022 TL prices)

	Year 1	Year 10	Year 20	Year 30	Year 40
(1) Savings on Coping Costs for Non-drinking Water	17,255,561	43,873,459	63,085,432	71,943,944	80,802,455
(2) Savings on Coping Costs for Drinking Water	67,469,743	79,031,996	91,878,943	104,725,890	117,572,837
(3) Savings on Electricity Previously used by Pumps in old Municipality Water system	2,290,032	2,682,474	3,118,520	3,554,566	3,990,612
(4) Total Savings on Coping Costs for Water (TL)	87,015,337	125,587,928	158,082,895	180,224,400	202,365,904
(5) PV of Total Savings on Coping Costs for	1,642,510,121				

Water @8% (PV of Benefits (4))					
(6) Investment Cost of the Water Storage Tank (TL)	85,441,520				
(7) Investment Cost of rehabilitating the water supply network (Economic Cost) (TL)	170,660,000				
(8) Total Water now pumped through Central Water Storage Tank (m^3)	3,686,749	4,318,545	5,020,541	5,722,536	6,424,532
(9) Cost to pump 1 cubic meter of water to municipal water storage tank (TL)	3.0	3.0	3.0	3.0	3.0
(10) Operating costs of Central Water Storage Tank (OC of water pumps used) (TL) [(8)*(9)]	11,059,223	12,954,435	15,060,228	17,166,020	19,271,812
(11) Total Investment Costs (TL) [(6)+(7)+(10)]	267,160,742	12,954,435	15,060,228	17,166,020	19,271,812
(12) Total Economic Costs (TL) [11]	267,160,742	12,954,435	15,060,228	17,166,020	19,271,812
(13) PV of Total Economic Costs @8% (PV of Costs)	427,193,845				
(14) Benefit to Cost Ratio	3.84				
(15) Net Benefit of Intervention (TL) [(12)-(4)]	(180,145,405)	112,633,493	143,022,667	163,058,380	183,094,092

(16)	PV of Net benefit from intervention @8% (TL)	1,215,316,276

Line 4 in Table 16 shows the benefits realized as total savings on coping costs for water with line 2 being the present value of those benefits. Operating costs of the central water storage tank (Line 10) stem from the cost of electricity needed to run the water pumps that send water to the tank. It is found by multiplying the total water now pumped to the central water storage Tank (Line 8) by the cost to pump 1 cubic meter of water to the tank (Line 9). Total investment costs (Line 11) are found by adding lines 6,7 and 10. Line 11 is simply the present value of total economic costs.

The benefit to cost ratio (Line 14) is found by dividing the present value of total savings on coping costs for water (Line 2) by the present value of total economic cost (Line 11). After taking into account all factors a benefit to cost ratio of 3.84 is found. The implementation of the project within Famagusta would return a real economic benefit 3.70 times the real cost of the project after discounting all benefits to the current year 1. Net benefit of intervention (Line 13) is simply the removal of the total economic costs from the total savings on coping costs for water (benefits). The present value of net benefits of the project for Famagusta in year 1 is 1,215,316,276 TL (81,894,628 USD).

4.8 Extension of Analysis to the Total Population of TRNC

Water systems across all districts within the TRNC are facing the same issues currently present in Famagusta minus the rehabilitated water distribution network in each district. Due to the fact that the same issues plague other districts, the base analysis conducted in Famagusta can be extended to the rest of the country by first finding the net benefit per capita of the project and then multiplying it by the total population of TRNC. Table 17 presents how this is done.

Table 17: Extension of Analysis to all of TRNC (Constant 2022 TL prices)

	Year 1	Year 10	Year 20	Year 30	Year 40
(1) Total Annual Water Consumption Per capita (m^3)	62.20				
(2) Levelized of Total Coping Costs per m^3 of Water (TL/m^3)	28.18				
(3) Benefit Per capita (LC) [(1) * (2)]	1,724	1,724	1,724	1,724	1,724
(4) Population of Famagusta (#)	59,298	69,460	80,751	92,041	103,332
(5) Total Economic Costs of Intervention (TL)	267,651,407	13,529,186	15,728,406	17,927,625	20,126,845
(6) Total Cost of Rehabilitation of Water Supply System Per Capita (TL) [(5)/(4)]	4,505	187	187	187	187
(7) Net Benefits Per Capita (TL) [(3)-(6)-(8)]	(2,781)	1,538	1,538	1,538	1,538
(8) Present Value of Net Benefits Per capita (TL) @8%	15,487				
(9) Total Population of TRNC (#)	386,946				
(10) Present Value of Total Net Benefits of Total Population of TRNC (TL) [(10)*(11)]	5,992,681,372				

As shown in Table 17, we begin with calculating benefits per capita (Line 3) by multiplying the total annual water consumption per capita in cubic meters (Line 1) by the levelized total coping costs per cubic meter of water (Line 2). The cost of rehabilitation of the water system per capita (Line 6) is found in a similar fashion by dividing the total economic costs of the project in Famagusta (Line 5) by the population of the same district (Line 4). Net benefit per capita is found by the removing both the total cost of water supply system rehabilitation per capita (Line 6) from the benefit per capita (Line 3). The present value of the benefits per capita over the next 40 years is calculated (Line 8) and then multiplied by the current population of TRNC (Line 9). This results in an underestimated economic net present value of benefits of 5,992,681,372 TL (403,819,499 USD) for the total population of TRNC. This value is an underestimate because the population of TRNC is held constant over the next 40 years. In reality, the population of TRNC would increase over time, resulting in a higher present value of benefits throughout the lifetime of the project.

There is one additional factor that comes into play when looking at costs incurred by municipalities within TRNC that is not considered for Famagusta since its water distribution network has already been fortified. The pipes of distribution networks in almost all districts within the country require rehabilitation. Remediating these pipes would overall reduce the number of leakages even in the presence of increased water pressure. In other words, rehabilitation of the water distribution network would still result in a net decrease in leakages even after water pressurization (increased water pressure would initially cause an increase in leakages in the absence of pipe rehabilitation). This would reduce the amount of water that the municipalities of TRNC would need to buy in order to supply households with the amount of water required for consumption as the water lost due to leakages are heavily reduced.

Chapter 5

SENSITIVITY ANALYSIS

As the project extends out to 40 years in the future uncertainties need to be taken into consideration. Certain variables that would have the biggest effects on the project if they were to deviate from estimates need to be identified. This is where a sensitivity analysis comes into play by altering suspected variables one at a time while holding all other factors constant and recording their corresponding impact on the metrics used to measure project outcomes, notably the economic net present value of the project and the benefit to cost ratio. The four variables chosen were the discount rate used, investment cost overruns or underruns, weighted average price of drinking water per liter and the price of electricity per kWh. The sensitivity analysis is conducted within the Famagusta district.

5.1 Discount Rate

Table 18: Discount Rate Sensitivity Analysis - Base Case: 8.00% (Constant 2022 TL prices)

		Levelized Cost	**Water Users**	**Benefit to Cost**
Discount Rate	**ENPV**	**LC of Water**	**Benefits**	**Ratio**
8.00%	1,215,316,276	28.18	87,015,337	3.84

3.00%	2,589,153,862	27.4	86,194,364	5.33
4.00%	2,180,021,938	27.5	86,349,052	4.99
5.00%	1,855,986,541	27.7	86,508,708	4.67
6.00%	1,596,601,486	27.9	86,673,124	4.37
7.00%	1,386,783,561	28.0	86,842,078	4.09
8.00%	**1,215,316,276**	**28.2**	**87,015,337**	**3.84**
9.00%	1,073,791,318	28.3	87,192,661	3.62
10.00%	955,854,659	28.4	87,373,808	3.42
11.00%	856,666,025	28.5	87,558,538	3.23
12.00%	772,508,728	28.6	87,746,614	3.07
13.00%	700,506,150	28.7	87,937,807	2.92
14.00%	638,414,321	28.8	88,131,894	2.79
15.00%	584,469,162	28.9	88,328,665	2.66

The discount rate used for the analysis has the largest impact on the outcomes of the study with mere 1% changes in the discount rate altering the ENPV and Benefit Cost Ratios by over 10%. Selecting an appropriate discount rate is key to the study. The base case utilizes the discount rate used throughout North Cyprus.

5.2 Cost Overruns

Table 19: Cost Overruns Sensitivity Analysis - Base Case: 0.00% (Constant 2022 TL prices)

		Levelized Cost	Water Users	Benefit to Cost
Over/Underrun	**ENPV**	**LC of Water**	**Benefits**	**Ratio**
0.00%	1,215,316,276	28.18	87,015,337	3.84
-30.00%	1,292,146,732	28.2	87,015,337	4.69
-25.00%	1,279,341,656	28.2	87,015,337	4.52
-20.00%	1,266,536,580	28.2	87,015,337	4.37
-15.00%	1,253,731,504	28.2	87,015,337	4.22
-10.00%	1,240,926,428	28.2	87,015,337	4.09
-5.00%	1,228,121,352	28.2	87,015,337	3.96
0.00%	**1,215,316,276**	**28.2**	**87,015,337**	**3.84**
5.00%	1,202,511,200	28.2	87,015,337	3.73
10.00%	1,189,706,124	28.2	87,015,337	3.63
15.00%	1,176,901,049	28.2	87,015,337	3.53
20.00%	1,164,095,973	28.2	87,015,337	3.43
25.00%	1,151,290,897	28.2	87,015,337	3.34

30.00%	1,138,485,821	28.2	87,015,337	3.26

Careful planning and execution are key when it comes to project implementation however, cost overruns are likely to occur. Although the presence of overruns has a considerable impact on the size of the ENPV, the project is still completely viable even at overruns beyond 30%.

5.3 Weighted Average Price of Drinking Water per Liter

Table 20: Weighted Average Price of Drinking Water per Liter Sensitivity Analysis - Base Case: 1.17 LC/Liter (Constant 2022 TL prices)

		Levelized Cost	Water Users	Benefit to Cost
LC/Liter	**ENPV**	**LC of Water**	**Benefits**	**Ratio**
1.17	1,215,316,276	28.18	87,015,337	3.84
0.57	679,490,594	18.78	52,380,145	2.59
0.67	768,794,875	20.35	58,152,677	2.80
0.77	858,099,155	21.91	63,925,209	3.01
0.87	947,403,435	23.48	69,697,741	3.22
0.97	1,036,707,716	25.05	75,470,273	3.43
1.07	1,126,011,996	26.61	81,242,805	3.64
1.17	**1,215,316,276**	**28.18**	**87,015,337**	**3.84**

1.27	1,304,620,557	29.74	92,787,869	4.05
1.37	1,393,924,837	31.31	98,560,401	4.26
1.47	1,483,229,118	32.87	104,332,933	4.47
1.57	1,572,533,398	34.44	110,105,465	4.68
1.67	1,661,837,678	36.01	115,877,997	4.89
1.77	1,751,141,959	37.57	121,650,529	5.10

Drinking water amounts consumed are dwarfed in size when compared to non-drinking water usage however, given that the average price of drinking water per liter is exponentially higher than the municipal water supply; changes in the average price of drinking water would heavily alter amount of expenditure on current drinking water sources once project implementation is complete. Increases in the average price of drinking water obtained from current sources would increase potential benefits in coping costs saved once residents switch over to the now clean drinking water arriving from the municipality while decreases in the price of drinking water would decrease potential benefits in coping costs saved.

5.4 Price of Electricity

Table 21: Price of Electricity Sensitivity Analysis - Base Case: 2.70 LC/kWh

		Levelized Cost	Water Users	Benefit to Cost
Electricity Price	**ENPV**	**LC of Water**	**Benefits**	**Ratio**
2.70	1,215,316,276	28.18	87,015,337	3.84
1.65	1,247,836,093	27.82	84,812,465	4.46
1.80	1,243,190,405	27.87	85,127,161	4.36
1.95	1,238,544,717	27.92	85,441,857	4.26
2.10	1,233,899,029	27.97	85,756,553	4.17
2.25	1,229,253,341	28.02	86,071,249	4.08
2.40	1,224,607,653	28.08	86,385,945	4.00
2.55	1,219,961,965	28.13	86,700,641	3.92
2.70	**1,215,316,276**	**28.18**	**87,015,337**	**3.84**
2.85	1,210,670,588	28.23	87,330,033	3.77
3.00	1,206,024,900	28.28	87,644,729	3.70
3.15	1,201,379,212	28.33	87,959,424	3.64
3.30	1,196,733,524	28.38	88,274,120	3.57
3.45	1,192,087,836	28.43	88,588,816	3.51

3.60	1,187,442,148	28.48	88,903,512	3.45

The price of electricity per kWh in this study is involved in the operation of the water pumps and water booster pumps to deliver water into households. While WP and WBP operating costs are present in every household, they shape a small part of the overall picture of coping costs and therefore have a significant yet weak effect on the outcome of the project.

Overall, the most important two variables to keep an eye on moving forward are cost overruns and the price of drinking water obtained from current sources as they have large enough impacts on the outcome of the project to warrant attention.

Chapter 6

CONCLUSION

Provision of affordable (or even free) and potable drinking water is a goal that every society wishes to achieve. Many developed nations have more or less achieved such a goal with developing nations lagging behind. The current water supply system provided in North Cyprus is not up to par with the level of development currently reached by the country and therefore requires rehabilitation.

The Northern Cyprus Water Supply project was proposed and implemented to combat the currently inadequate water supply system using an 80km pipeline that runs under the Mediterranean Sea delivering 75 million cubic meters of water annually to the TRNC. The project was made up of 4 phases with the third phase completed by the end of 2016. The fourth phase which involved the rehabilitation of the water distribution network within districts in TRNC came to a halt due to a lack of funds. This resulted in a water supply that was intermittently available due to the leaking, unpressurized pipes. Unpressurized pipes also allow tainted water to enter and mix with the potable water treated and supplied by the municipality making it unsuitable for drinking and cooking purposes. The only district in which the water distribution network was rehabilitated is Famagusta due to funding from a prior EU project. The water supply in Famagusta is still unpressurized due to the lack of central water storage tanks at a sufficient level of elevation to provide such pressure.

Due to the intermittent nature of the municipal water supply, residents of North Cyprus must incur averting expenditures in the form of pumps and tanks in order to secure water availability within their own homes. In addition, residents must purchase drinking water from vendors at relatively expensive prices due to the unpotable water provided by the municipality. Averting expenditures on certain apparatus (tanks and pumps) provide circumstances where the water stored at households becomes even more polluted due to plastic from storage tanks breaking down in the water.

This analysis looks at the economic costs and benefits of implementing a central 10,000 cubic meter water storage tank at a sufficient level of elevation that would pressurize water within the district of Famagusta over the next 40 years, eliminating the need for residents to install large pieces of equipment that degrade the water quality even further while also taking up valuable real estate and sullying the appearance of the district. The economic net present value of such a project is found to be 1,215,316,276 TL (81,894,628 USD) over the next 40 years for the district of Famagusta. Extending the analysis to the rest of the TRNC and assuming the same project is implemented throughout all districts within the country results in an ENPV of 5,992,681,372 TL (403,819,499 USD). This value of ENPV takes into account both the cost of implementing a central water storage tank along with the rehabilitation of water distribution networks within each district. The discrepancy between the price of potable water sold by vendors per cubic meter and the price of water supplied by the water that could potentially be potable is large enough to result in such large economic benefits to the society. The willingness to pay of consumers for an improved water supply is evident throughout this study and the benefits to the country as a whole from an economic point of view justify the implementation of such a project and may bring North Cyprus one step closer towards international recognition.

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APPENDICES

Appendix A: Survey for Water Users - Su Kullanıcıları için Anket

Your participation in this survey is voluntary. You may refuse to take part in the research or exit the survey at any time. You are free to decline to answer any particular question you do not wish to answer for any reason. Your refusal to participate or withdrawal of consent will not affect our treatment of you in any way. If you wish to remove your answers, please contact the Economics Department of Eastern Mediterranean University. Thank you for your participation, understanding and cooperation.

Bu ankete katılımınız isteğe bağlıdır. Araştırmaya katılmayı reddedebilir veya istediğiniz zaman anketten çıkabilirsiniz. Herhangi bir sebepten dolayı cevaplamak istemediğiniz soruları boş bırakmakta özgürsünüz. Ayrıca ankete katılmayı reddedebilir veya katıldıktan sonra geri çekilmekte de özgürsünüz, bu durumda size yönelik muamellemiz hiçbir şekilde etkilenmeyecektir. Katılım sonrası ileri bir tarihte cevaplarınızı geri çekmek istiyorsanız Doğu Akdeniz Üniversitesi Ekonomi Bölümü ile iletişime geçebeilirsiniz.

1. Are you renting your living space or did you buy it? --- Yaşam alanınızı kiralıyor musunuz yoksa satın mı aldınız?

   - ☐ Renting --- Kiralıyorum
   - ☐ I bought it --- Satın aldım

2. Which of the following method do you use in your house to cope with the unreliable water supply? Check all that apply --- 1. Evinizde istikrarsız su kaynağı ile başa çıkmak için ağıdaki yöntemlerden hangisini kullanıyorsunuz? Geçerli olan her şeyi seçiniz.

   - ☐ A water tank of one cubic meter on the roof of your residence. --- Evin çatısında bir metreküp su deposu.
   - ☐ A water tank of two cubic meters on the ground floor your house. --- Evin zemin katında iki metreküplük su deposu.

- ☐ A water pump of one horsepower --- Bir beygir gücünde bir su pompası.
- ☐ A water booster pump on the roof of the building for pressure --- Basınç için binanın çatısında hidrofor pompası.
- ☐ Other --- Diğer
- ☐ None --- Hiç
- ☐ I don't know --- Bilmiyorum.

3. How many years does your water tank last? --- Su deponuz kaç yıl dayanıyor?

   - ☐ I don’t know --- Bilmiyorum.
   - ☐ *Number*

4. Which of the following averting actions do you use to drink and cook against the low quality of water? Check all that apply. --- Düşük kaliteli suya karşı su içmek veya yemek pişirmek için aşağıdaki önleme eylemlerinden hangisini kullanıyorsunuz? Geçerli olan her şeyi seçiniz.

   - ☐ Buy bottled water for drinking and cooking --- Şişelenmiş veya damacana içme suyu satin alıyorum.
   - ☐ Use water purification systems in the house --- Evde su arıtma sistemleri kullanıyorum.

5. If you buy bottled water (19 liters) How many bottles of water do you use per week? --- Damacana su alırsanız haftada kaç damacana su alırsınız?

6. How many people are using the water you order on a consistent basis? In other words, how many people live at this household? --- Sipariş ettiğiniz suyu kaç kişi düzenli olarak kullanıyor (veya hanenizde kaç kişi yaşıyor).

7. How many 0.5-Liter bottles of water do you buy or fill per week? --- Haftada kaç adet 0.5-litrelik şişe su alıyorsunuz?

8. How many 1-Liter bottles of water do you buy or fill per week? --- Haftada kaç adet 1-litrelik şişe su alıyorsunuz?

9. How many 1.5-Liter bottles of water do you buy or fill per week? --- Haftada kaç adet 1.5-litrelik şişe su alıyorsunuz?

10. How many 5-Liter bottles of water do you buy or fill per week? --- Haftada kaç adet 5-litrelik şişe su alıyorsunuz?

Appendix B: Water Tank and Hydrofoil Usage Survey

1. What is the building name?
2. How many apartments are there in the building?
3. How many 2m3 Water tanks are being used under the building?
4. How many water pumps are being used at the bottom of the building?
5. How many 1m3 Water tanks are being used on the roof of the building?
6. How many water booster pumps are being used on the roof of the building?