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The Use of Economic Science in SWITCH: A case study of Beijing, China

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SWITCH Document The use of economic science in sustainable urban water management: Case study of Beijing city[1]
Audience This document is targeted at policy makers, local government engineers, accountants, state or federal planners, etc. The document was prepared for an audience both inside and outside the SWITCH consortium. For consortium members it gives the current draft SWITCH approach to urban water management. Consortium members are invited to take this into account while doing the thematic research, and to give further feedback. The external audience consists of urban water managers that would like to rethink their approach to urban water management.
Purpose The purpose of the document is to explore the use of economic science to assess alternative approaches to sustainable urban water management. It aims to find out whether the proposed systems are economically viable alternatives to the existing system by making a comparison between the alternative approaches. The expected results of the research should help decision makers to select the more suitable solutions.
Background The document is a step towards the development of the overall SWITCH approach.
Potential Impact The research will be the first opportunity to find out how different research projects within SWITCH have dealt with economic and financial issues related to the innovations that are suggested. By using a uniform cost benefits framework it may be possible to compare the results and to indicate the advantages of certain solutions.
Issues
Recommendations

[1] Originally the report was entitled "The demo projects and selected cities on the different ways of financing the relevant infrastructure and the cost recovery system chosen". Because of limited material being available we concentrated on the Chinese case.

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Summary

Key words: Economic analysis, Financial analysis, Urban water management

The research tries to explore the financial and economic implications of alternative approaches by making a comparison between the cost and benefits of these alternatives. The aim of the research is to find out whether the proposed technological options in the SWITCH project are viable alternatives to the existing one. The expected results of the research should help decision makers to select the more suitable solutions.

Evaluating the relevant infrastructure in demo projects and selected cities requires cost-benefits analysis to determine the point of view of society and from the point of view of the investor a financial analysis of the project is carried out. The methodology developed for the analysis of demonstration projects is actually used for three Demo projects in Beijing: the Qing project (a grey water reclamation project), the BNU project (same technology) and the An project (a rainwater harvesting project).

The research will be the first opportunity to find out how different research projects within SWITCH have dealt with economic and financial issues related to the innovations that are suggested. By using a uniform cost benefits framework it may be possible to compare the results and to indicate the advantages of certain solutions.

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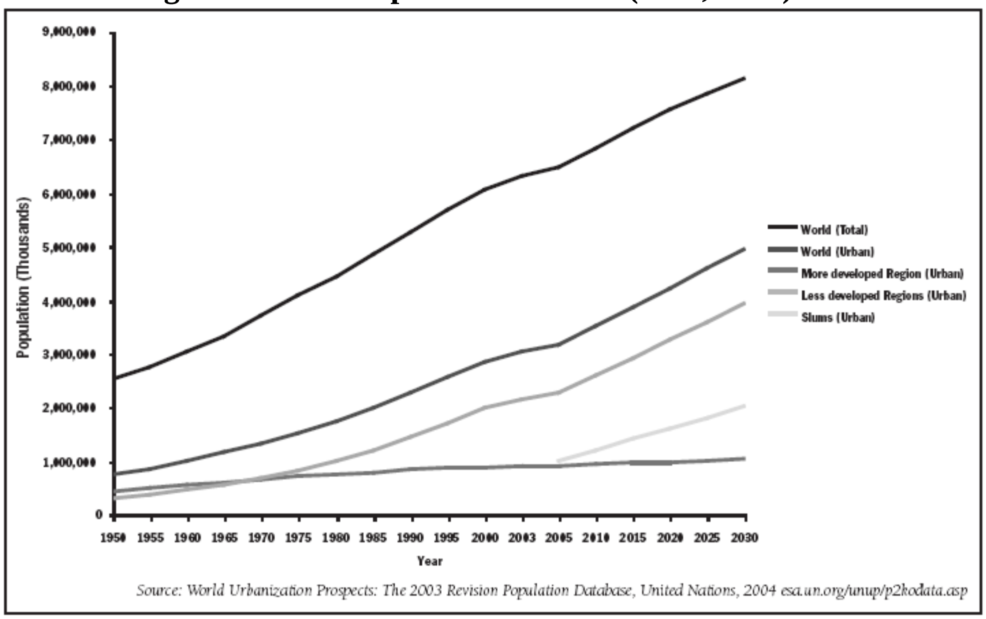
1. Background introduction

1.1 Background

35 years ago the urbanized population represented only 37% of the total population, but presently around 50% of the world's population inhabits urban areas, and the urbanized population may be over 60% of the total people by the year of 2025 (Rees, 2006). It is shown in the figure 1 that the urbanization growth in developing countries is faster than the growth in developed countries. In the developing countries the urbanized population proportion may increase from 42% to 57% by year 2030 (Jenerette and Larsen, 2006). Moreover the number of megacities which have more than 5 million residents is expected to increase globally from 46 to 61 between 2015 and 2030 with disproportionate increase in Asia and Africa (UN, 2004).

Figure 1 Urban Population Growth (Rees, 2006)



Increasing population is causing the dramatic increase of urban water utilization. The global urban water utilization for living increased over 20 times within 100 years: in 1900, it was $200*10^8m^3$; in 1950, it was $600*10^8m^3$; in 1975, it was $1500*10^8m^3$; in 2000, it was $4400*10^8m^3$ (Bao and Fang, 2007). It is predicted that global urban water utilization for living in the year of 2050 will equal to global water utilization in 2004 (Song et al., 2004).

The water resource available to the human being in the world is limit. Only 2.5 % of the earth's 1386 million cubic kilometers of water is fresh water and nearly one third of this smaller amount is available for human use (Postel et al., 1996). For example, the renewable water resources of China is only 2205 m3 per capita per year, which is ¼ of the average world level (FAO, Water resource, Development and Management Service, 2003). Per capita water availability in the 3-H basins of north China (Hai, Huai,and Huang) is around 500 m^3/year, which is well below the 1,000 m^3/year standard for water stress (WorldBank, 2007a). In Beijing the total availability of water resources per capita per year is only 300 cubic meters, 1/8 of the nation's average and 1/32 of the world's average (People's Daily, 2000). Not only the arid areas but also some regions with normally plentiful water resource are affected by the water crisis. Many parts of European countries, for instance, have suffered successive droughts over the last few years, with the result that some watercourses have dried up (Lazarova et al., 2001). In this report we will show how this conceptual framework can be used for different technological options: for example, centralized versus decentralized water treatment, river bed infiltration versus wetlands, or groundwater infiltration versus aquifer refill.

The research of theme 6.4 is emphasizing the financial and economic analysis of the urban water management system. It tries to explore the financial and economic implication of the alternative approaches by making a comparison between alternative options. The aim of the research is to find whether the proposed systems in the Switch project are viable alternatives to the existing one. The expected results of the research could assist decision makers to select a more suitable plan.

In this report we will first discuss the two main approaches to evaluating infrastructure: Cost benefit analysis (CBA) and Lifetime cost analysis, and then some other methods will be presented. Subsequently some demos will be described to come up with a conceptual framework incorporating the most relevant costs and benefits in the economic CBA. In chapter 4 different methods for comparing the costs and benefits will be compared. In the final chapter some conclusions will be drawn concerning the use of the conceptual framework in the Switch project and plans for citis like Beijing, Accra and Alexandria will be presented.

1.2 Different technological options: centralized versus decentralized water treatment

The urban water and wastewater treatment system has to been adapted to the changed environment. Centralized water and wastewater treatment, as the conventional system, has been applied over many decades in the developed countries. But this concept is increasingly challenged, especially in the developing countries. It is mainly for the reasons of sustainability of water resource usage. Additionally it is difficult to export the concept of centralized treatment system to water scarcity countries which are experiencing rapid urban growth and have not water treatment systems previously (Larsen and Gujer, 1997). Consequently in response to the deficiencies of centralized approaches, the potential benefit of adopting decentralized approach to sanitation and wastewater management is highlighted recently. Normally centralized system is used to describe system consisting of a sewer system that collects wastewater from households, small enterprises, industrial plants and institutions, and transports this ever changing mixture to a wastewater treatment plant. In contrast decentralized system makes a service closing to the point of origin. In the decentralized system, the wastewater is colleted and transferred to the plant, and then the treated water is reused and the remaining sludge is converted into the fertilizer. Decentralized system is regarded to be less resource intensive and more ecologically benign form of wastewater treatment and sanitation (Lens et al., 2001).

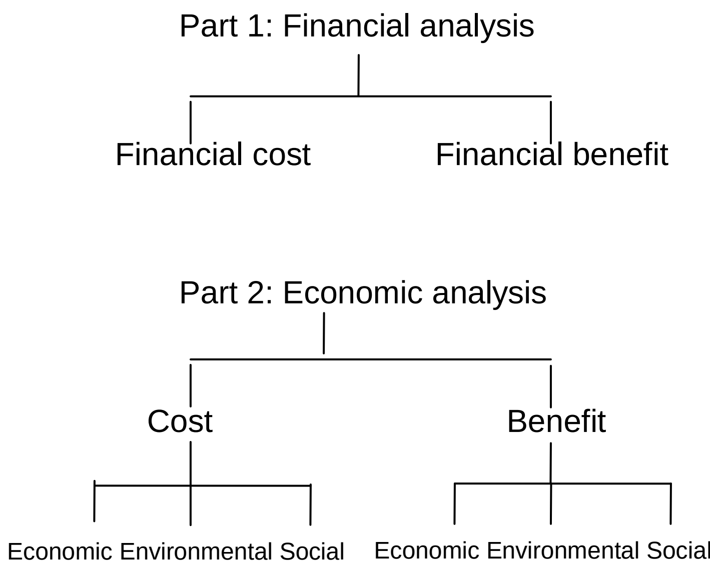
The arguments against centralized system are principally from the technological point of view. While the engineers try to make the production or service more effective than the present situation via the new technologies, the actual production usually does not realistic reflect the economic effectiveness when the new system is put into use. To reach competitiveness the new system must achieve both physical and economic competitiveness. So emphasis should be put into that a new technology is economically competitive as well.

Although the capital investment for decentralized system is generally less than for centralized system, financing the small decentralized systems still can meet the problem of lacking enough budgets on the initial investments. For example, California approved 37 projects to receive state grants or loans for construction of water reclamation projects, but actually most of projects obtained less than promised amount of funding assistance because of shortage of state funds(Mills and Asano, 1996). The projects without enough funding can not do the plant construction. Moreover, in the absence of adequate cost-recovery mechanisms, investment in wastewater management may become a financial liability and this may constitute a major hindrance to the sustainable operation of decentralized waste water treatment (Parkinson and Tayler, 2003). In Wuhan city of China, for instance, the operations of many small water reclamation plants have been suspended due to the shortage of capital for operating and maintenance (from interviews with the Wuhan Water Authority).

At this point the question should be raised whether the decentralized system is indeed the optimal alternative to a centralized system. Is the decentralized system economic competitive with the centralized system? The research of theme 6.4 will investigate and critically discuss this issue.

2. Research approaches

Figure 2 Two parts in the analysis



2.1 Financial analysis

Financial appraisal is the analysis to assess the financial performance of the proposed investment. Profitability is the basis of sound financial performance of a project, namely the profit of operation could at least cover the costs on the operation of the project. Obviously the rate of the reclaimed water charged from the consumers is the main revenue of the water recycling system.

At the early stage, frequently water reclamation projects are granted through government subsidies (Asano *et al.,* 1996, Mills and Asano, 1996, Ogoshi *et al.,* 2001). Nevertheless this could be unsustainable due to government budget restriction. Water supply benefits alone are insufficient to carry the investment costs of improving the effluent (Bixio *et al*., 2005). Several kinds of specific financial incentives have been identified in some countries. One example is a recent regulation allowing exemption of the user tax for reclaimed water in Spain (Mujeriego *et al.,* 2000). Another good example is accelerating depreciation of financial interest of the initial investment in the USA (US Executive Order 12803/1992) (Bixio *et al*.,2005).

The usual financing options for infrastructure are listed in the table 1 (Van Dijk, 2006). Furthermore, an idea of "innovative financing" is proposed by Houston (1995). It is defined to be reflective of and consistent with contemporary target such as sustainability and efficiency, and be responsive to the issue within a service area, and be affordable by those within the service area who are the project's beneficiaries. It means finance could be as flexible as the project to be financed with the unique design.

Table 1 Instruments for infrastructure finance

From more traditional finance	To more alternative finance
Loans or bonds Municipal Infrastructure Development Funds, for example ● Investment/capital funds ● Trust fund ● Endowment fund BOT (Build Operate Transfer) Subsidized entry fees Higher levels of government financed out of general or specific tax revenues State Level Finance Institutions	Microcredit to finance water connections Rotating savings and credit associations (ROSCAs) to link traditional savings with credit Private sector involvement Project finance Design, Finance, Build and Operate (DFBO) and ROT (Rehabilitation Operate Transfer) Hedging (futures/options) to cover risks Pooled Finance Development Fund

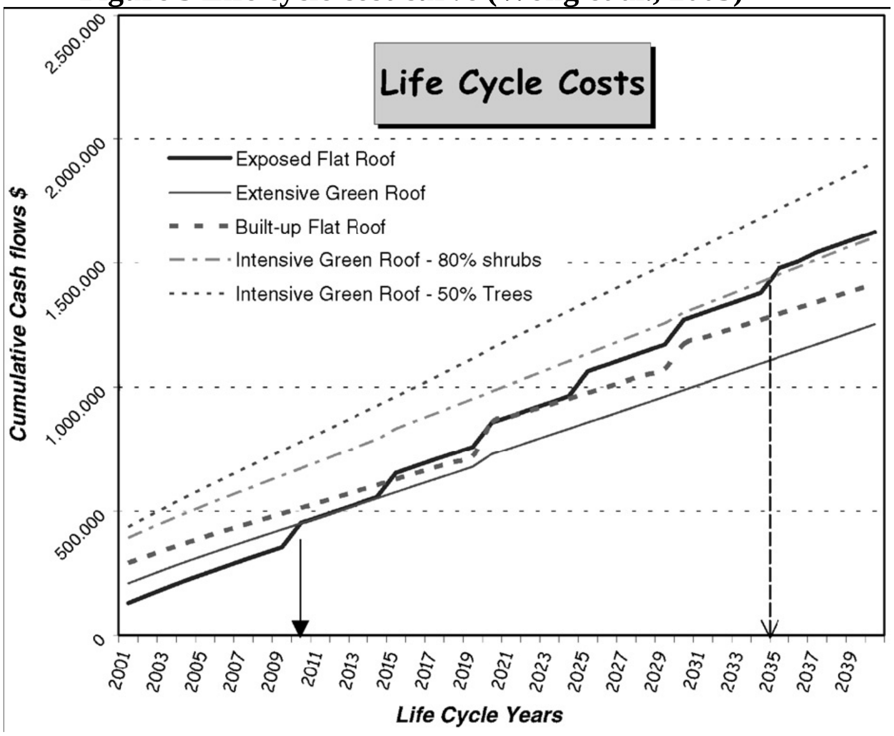
Source: Van Dijk (2006)

In the existing literature, the cost of water recycling project is estimated in different ways. Generally the emphasis is put on the cost of construction and the cost of operation and maintenance. For example, Gratziou *et al.* (2005) provided a comparative cost evaluation of eight different actived sludge and natural wastewater treatment systems including construction cost, energy and chemical costs, maintenance expenses and salaries. However it should be taken into consideration that the performance of a project consists of several stages: design or development of a concept, production or construction, operation and maintenance, and final disposal stage. The development cost of a project may include preparation expense and designing fees. Disposal can be a costly activity, but often benefit can be captured through reclamation of system components. Development cost and disposal cost account for certain proportion of the total investment, so they should not be neglected in the cost estimation. Accordingly attention should be given to the entire life of the project when estimating the cost.

2.1.1 Financial cost

Life cycle cost analysis method is a systematic analytical process for evaluating various designs or alternative courses of actions with the objective of choosing the best way to employ scarce resources (Durairaj et al., 2002). It lies not only in the determination of a total cost of a project alternative, but also in the ability to compare the cost of project alternatives and to determine which alternative provides the best value per euro spent. Figure 3 below is an example of life cycle cost curve, showing the change of the cumulative present equivalent life cycle cost within the utilization period and the different situation of the alternative. Experience has indicated that the commitment of these costs is based on decisions made in the early stages of the system life cycle, and more than half of the projected life cycle cost is committed by the end of the system planning and conceptual design, even though the actual expenditures are relatively minimal by this point in time (Fabrycky and Blanchard, 1991). Thus life cycle cost analysis approach enables various alternative projects to be compared over a specific period of time.

Figure 3 Life cycle cost curve (Wong et al., 2003)



According to the Model of Fabrycky and Blanchard, a general cost breakdown structure revealed in figure 4 specifies which cost should be considered into the whole life cost. The cost breakdown structure is the superiority of the model, which is a way of classifying cost and a basis for assessing the life cycle cost for each alternative being considered.

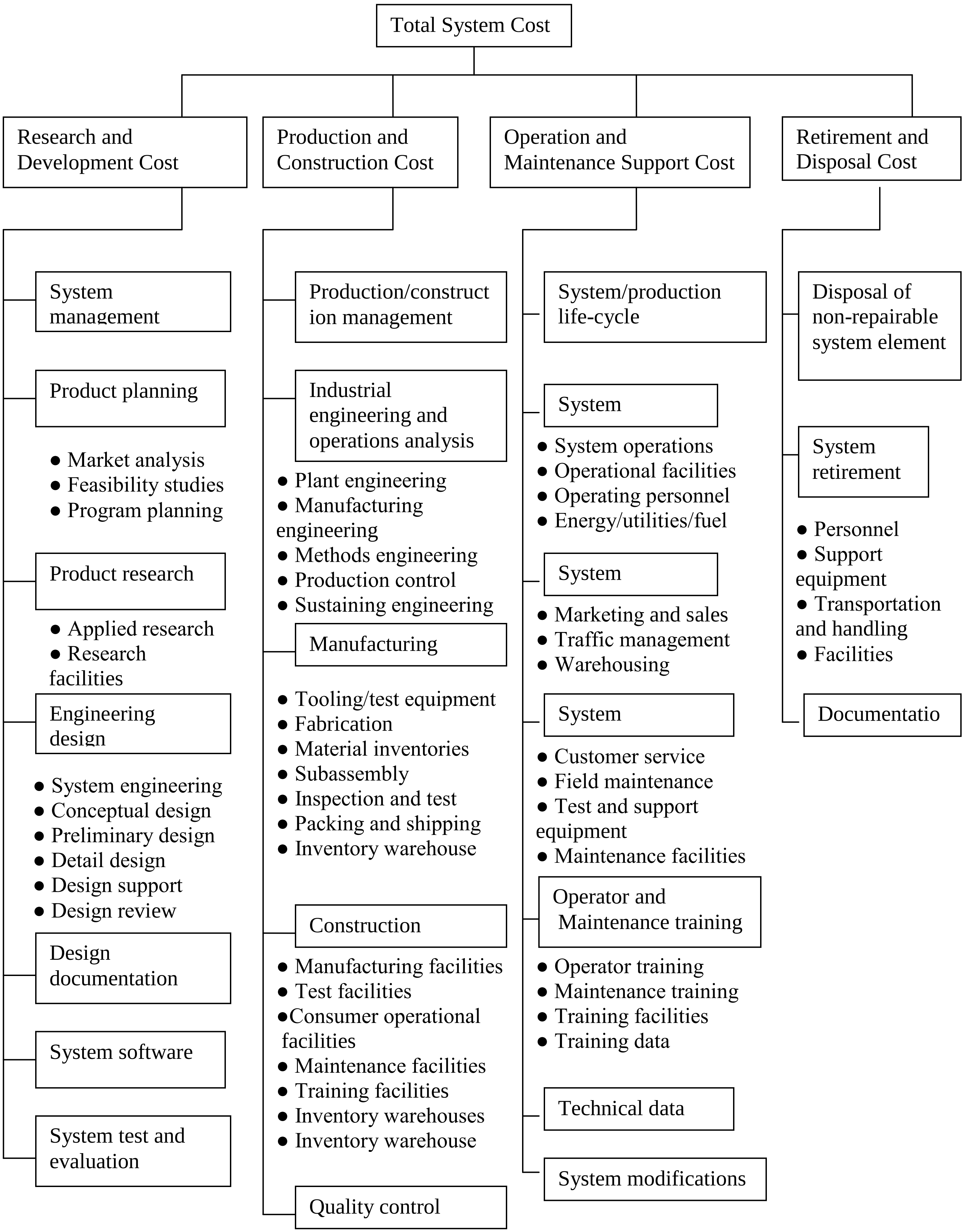


Figure 4 A general cost breakdown structure (Fabrycky and Blanchard, 1991)

From the cost breakdown structure, the total cost of a system is divided into four categories, namely development cost, construction cost, operation and maintenance cost and disposal cost. In terms of the breakdown of the Fabrychy and Blanchard (1991), the cost breakdown of the study is shown in the table 4 as the following. For example, to the project of wastewater reclamation and reuse, the development cost could be represented by the cost of project application or the expenditure on the preparation for the project. The disposal cost could be presented by the certain proportion of the total investment. The percentage number could be chosen in terms of the existing papers.

The life span of a project could depend on the life of machine used for the operation. Or we can choose three periods: 5 years, 10 years and 15 years, and then make evaluations in the three periods separately.

Table 2 The cost breakdown for the proposal project

Item	**Development cost**	**Construction cost**	**Operation and maintenance cost**	**Disposal cost**
Content	Land cost Design cost Preparation cost	Construction cost Equipment cost	Electricity Chemical Personnel Sludge disposal Pumping Reparation	According to relevant document: 10% of total investment

2.1.2 Financial benefit

The economic benefit of the Qing project is represented by the revenue of the project. The revenue amount depends on the reused water price and reused water production. The price of reused water is 1 yuan/m^3 in Beijing, which has not been changed for several years. About the reused water production, it is assumed to be the same level during the considered period. So the average reused water consumption in each year is calculated

The Beijing Normal University pays for the all operation and maintenance cost in each year. The value of the payment is 200,000 yuan/year. From the viewpoint of project manager, this amount could be regarded as the economic benefit of the project.

2.2 Economic analysis

The cost benefit analysis method is used for economic analysis. The cost benefit analysis approach is concerned with resource distribution in various sector based on the theory of resource allocation (Mishan, 1988). According to Boardman and Vinning's paper, cost benefit analysis can be thought of as providing a protocol to measure allocative efficiency in the economy (Boardman and Vinning, 1996). Although many economic methods have been proposed for the economic analysis, including multi-criteria analysis, cost effectiveness study, contingent valuation methods, and multiple goal programming

(Ashley et al., 1999; Braden and Van Ierland, 1999; Hauger et al., 2002), cost benefit analysis should one of the most appropriate methods to make economic analysis on water system.

Suggestions for cost benefit analysis by Brent (1996):

1) All benefits and cost are to be included, consisting of private and social, direct and indirect, tangible and intangible.
2) Benefits and costs are determined by the standard principles of welfare economics. Benefits are based on the consumer's willingness to pay for the project. Costs are what the losers are willing to receive as compensation for giving up the resource.
3) The social discount rate is to be discounted to get the annual net-benefit stream.
4) Constraints are not allowed for separately, but are included in the objective function. Financial constraints are handled for example by using a premium on the cost of capital, that is, the social price of capital is calculated which would be different from its market price.

Although Brent lists the context of cost benefit analysis, his second and third points are based on the assumption that if the private capital markets in a country were perfect and if there were no taxes or subsidies at the margin on profit and income, the market interest rate would be the appropriate rate for discounting future cost and benefit. The main characteristic of cost benefit analysis method is that it is based on many assumptions, which is also a limitation of this method.

The social price, mentioned in the fourth Brent's viewpoint, is actually called shadow price in terminology. In the real word, market imperfections such as tariff, quotas and monopolies create distortions in demand and supply. Hence there is little chance that the market price will reflect the true economic value and cost of inputs and outputs. In order to demonstrate the real measurement, the market prices are required to be adjusted, resulting in a shadow price.

Benefits theoretically include all changes in resource use and services level. Estimating benefits is a complicated matter mainly because it is difficult to decide which benefits to be included in the analysis and some benefits are very intangible and difficult, if not impossible, to convert into money term (Hauger et al., 2002). As a result, few studies do a quantitative analysis on the social economic benefits, in spite of lots of papers on benefit analysis (Birol et al., 2005; Psychoudakis et al., 2005).

A main concern of the cost analysis is which cost should be included and how to estimate their value. The concept of "full cost" is used accordingly. Full cost is supposed to cover all costs pertained to water management. In the opinion of Rogers et al. , the full cost of a water project consists of the capital cost, operation and maintenance cost, opportunity cost, economic externalities and environmental externalities (Rogers et al., 2002). Reliable cost estimation is essential in the water sector. However the calculation of all the cost components for complying with the full cost recovery principal is always difficult (Tsagarakis, 2005). A well know problem is that environmental damages resulting from the economic activity cannot be valued on the basis of existing market prices (Braden and Van Ierland, 1999).

Table 3 Three main items for economic analysis

Item	Content
Economic costs and benefits	The operational cost is listed below. The benefit could be the revenue from the project or the reduced outflow.
Social costs and benefits	The external social impact caused by the project, which is difficult to evaluate directly.
Environment costs and benefits	The external environmental impact caused by the project, which is difficult to evaluate directly.

Table 4 Identification of social and environmental externalities

Groups	Externalities
Water infrastructure	Avoids constructing facilities to capture and store freshwater Avoid water purification costs Avoid constructing pipes and water distribution costs
Reuse of pollutants	Reuse of nitrogen in agriculture Reuse of phosphorous in agriculture Reuse of sludge in agriculture and gardening Reuse of thermal energy
Use of the resource	Increase the quantity of water available Guarantees supply in times when there is a shortage Water quality adapted to different use is obtained
Public health	Biological risks associated to wastewater reuse Chemical risks associated to wastewater reuse
Environment	Increase in the level of rivers Avoids overexploitation of water-bearing resources Avoid water pollution Allows wetland and river habitat to be recovered Increase in pollution due to smell and noise Decrease in the value of land nearby
Education	Raises social awareness of a new water culture

(Source from Hernandez *et al*., 2006)

In this research, all costs and benefits could be divided into three parts: economic, environmental and social costs and benefits. The content of each part are shown in the table 3.The economic costs could be classified as construction, operational and maintenance, and capital cost, which is presented in the table1. Both social and environmental costs and benefits are the external impact of the project. The identification of these impacts caused by the water reuse project is indicated in the table 3 (Hernandez *et al*., 2006). Any impact can be calculated in terms of monetary units. But there are a series of external influence for which no explicit market exists. The evaluation will be based on hypothetical scenarios or pattern observed in related markets. Furthermore, the weights to these cost and benefit components depend on their influence on the society or the economy.

The present research is supposed to facilitate the decision making on urban water management. The process of decision making is indeed an organized evaluation procedure. Given a set of alternatives, a set of consequences, and a correspondence between those sets, is required to facilitate the decision making. Consequently it is very important to translate individual preferences into collective preferences via providing useful and accurate suggestions to the decision makers. The multiple account spreadsheet-based frameworks would be sound approach to display the results. Through the framework, various perspectives on the proposed project are offered. It incorporates all the usual concerns of cost benefit analysis such as market failure, distribution of net benefits, risk, and environmental effect, and it provides a summary of project net benefits disaggregated by stake-holder groups. An example of the structure of spreadsheet is shown in figure 2 (Campbell and Brown, 2005).

2.2.1 Economic cost

Normally, the economic cost includes construction cost, operation and maintenance cost and capital cost. The classification of the economic cost is shown in the table 4. Because the projects are both small scale and they obtain certain subsidies for initial investment, the actual capital inputs afforded by the project manager are not large amount. So the capital cost is not considered in the study. Therefore, construction cost and O&M cost are taken into economic cost evaluation.

As there is not traded item in the economic cost and there is not big distortions in market price of wastewater treatment construction in Beijing, the market price could be regarded as economic value in the economic cost analysis.

Table 5 Classification of the economic cost

Construction Cost	Land, Building construction fee Network installation: pipes fee and sewage facilities, Costs of equipment
Maintenance and Operation Cost	Electricity, Chemical Cost, Personnel cost: salary and training, Reparation, Network maintenance
Capital Cost	Depreciation, Capital-financing cost (such as interest rate payment)

The figure 5 and figure 6 show the distribution of construction cost and O&M cost of the Beijing Qing project.

Figure 5 The distribution of construction cost

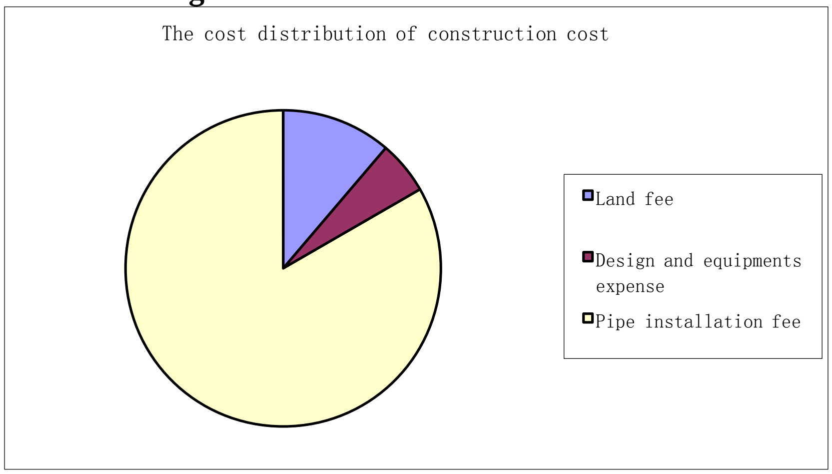
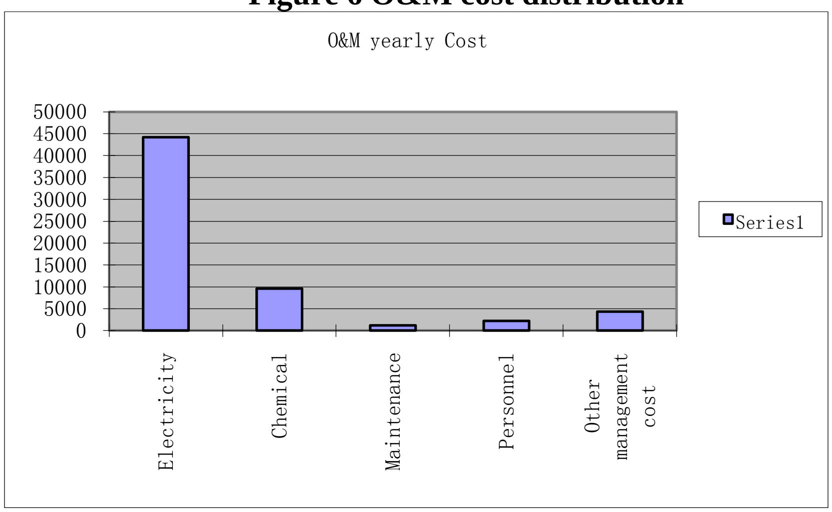


Figure 6 O&M cost distribution



2.2.2 Environmental Cost

The noise from the machine can not be neglected, which could become a pollution to environment. Valuation of noise impact is very complicated becasue there is not direct market price for noise effects. Few papers evaluate the noise pollution in China, and the existing studies mostly make evaluation in the national and regional level. For example, Wen and Chen estimates the noise pollution of China, and Liu valuates the noise pollution in Dalian city (Liu, 1999; Wen and Chen, 2007). For simplifying the determination, we make the valuation of the noise impact through converting the value of existing literature result. Wen and Chen (2007) also take the method of converting Liu (1999)'s result to valuate the noise pollution of China.

Liu (1999) makes a systematic estimation on the noise pollution in Dalian city through the method of Willingness To Pay. He finds that the estimated households who live in the high decibels areas, namely 66-70 decibels, would like to pay average 26 Yuan /month to eliminate the noise. So the noise pollution cost in Dalian could be regarded as around 26 Yuan/household each month which is around 9 yuan/person every month (Liu, 1999).

We valuate the noise pollution cost through converting the noise pollution value of Liu (1999). The conversation can be made in terms of the difference ratio between Dalian and Beijing city. According to Beijing statistic yearbook 2005, the average income of Beijing's resident is 1.5 times of the income of Dalian's people. Additionally the ratio of the average consumption amount between Beijing and Dalian is also 1.5. So we assume all kinds of costs in Beijing are 1.5 times more than the costs of Dalian city. Moreover, the noise of treatment plant is assumed to be 66-70 decibels which is the same to the noise level of the study of Liu (1999).

The value of noise impact could be obtained through multiplying the unit cost and the affected people amount, namely, the noise impact = cost per person × affected people amount. The unit cost of noise pollution is 9 yuan/person in Dalian city. Through value conversation, the cost of noise pollution in Beijing city could be 13.5yuan/ person. In the Qing project around 30 persons are affected by the noise, and in the BNU project around 10 persons are affected.

2.2.3 Social Cost

The wastewater treatment plant provides non-potable water for toilet flushing and green lands irrigation. It is often thought by the engineers that the non-potable recycling water has no negative impact on human health because the amount of pathogens in the recycling water is very small. However human health risks depend on the source of the pathogens, the treatment applied and the exposure route (Ottoson and Stenström, 2003). It means the treatment process and exposure route could also become the causes of health risk. In Beijing, there are no standard techniques for the recycling of water process, so each wastewater recycling plant has its unique technique. Even though the water quality reaches the regulated standard for recycling water, there is still a certain amount of bacteria in the water. Moreover, the "surface irrigation technique" could be negative to the health risk (Christova-Boal et al., 1996). The Qing project uses the "spraying irrigation technique", which is a typical surface irrigation method. As a result, the pathogen in the recycling water may be left on the grass, and then transfer to the residents who come in contact with the grass, and may finally lead to epidemic diseases. The current study assumes that the non-standard wastewater treatment process and surface irrigation method may cause health risks in the Qing project. The present paper would determine the increase of health risks after the construction of a water recycling plant using the water for irrigation.

Valuation of health impact is very complicated because there are no direct market prices for human mortality and morbidity. Economists try to solve these problems through determining the value of statistical life, willingness to pay, and adjusted human capital. These methods are the principal economic methods for valuing the health impact. Because of limitations, these economic methods have to be applied to big samples with a large amount of data. In the literature the valuation of health risk is calculated at the national or regional level (Zhang, 2002). Valuing the environmental health impact at the level of one project is a neglected issue. The present paper would adopt the indirect valuation method to assess the health impact from a small wastewater recycling plant.

For the purposes of this study, Disability Adjusted Life Year (DALY) is taken as a measurement unit for the impact on human health. DALY is an index of health risk, developed by the World Health Organization (WHO) and the World Bank (Murray and Lopez, 1997; Zhang, 2002). DALY is a method to measure the disease burden, which considers the impacts of life loss caused by death, healthy life loss caused by deformity after disease, and healthy life years (WHO, 2005). It is the sum of discounted and age-weighted years of life lost. One DALY corresponds to one lost year of healthy life, and the burden of diseases to the gap between current health status and an ideal situation where everyone lives until old age, free of diseases and with no disabilities (WHO, 2007). DALY is used in many studies for measuring the health risk. For example, (Aramaki et al., 2006) find that after building the wastewater treatment, the disease burden of a community changed from 60 DALYs per year to 5.7 DALYs per year. In this study, DALY is a bridge to convert the monetary value of health risk from national level to the scope of a small project. Moreover, diarrhoea disease is estimated to be the largest contributor to the burden of water-related disease (OECD, 2007). Many papers limit the evaluation to diarrhoea disease risk (OECD, 2007; WHO, 2007; WorldBank, 2007b) while there are other microbial contaminations included in water pollution. The present study also focuses on health risk related to the diarrhoea disease risk. Therefore, the health risk can be determined by multiplying the DALY number of diarrhoea risk caused by the project and the DALY cost rate.

The figures in table 6 are estimated by the WHO (2004) and are based on the information provided by China concerning the levels of child mortality (between the ages of 0 and 5) in an earlier time period and adult mortality (between the ages of 15 and 60). The age-standardized DALY rate means the standard DALYs with age-weighting and time discounting. Because both child and adult with different ages are involved in the estimation, it is more precise to use the age-standardized DALYs rate: $442*10^{-5}$ DALYs per person for the evaluation. OECD finds that 88% diarrhoea disease is attributed to water and sanitation (OECD, 2007). Thus the DALY rate of diarrhoea disease due to water pollution is $442\times10^{-5} \times 0.88= 389*10^{-5}$ DALY/person. Since Beijing has the highest diarrhoea incidence, the average DALY rate of China could be regarded as the DALY rate of Beijing.

Table 6 The DALYs in China (population: 1302,307,000)

Total DALY number (caused by all diseases)	200,273,000
DALY number (caused by Diarrhea)	5055,000
Age- standardized DALY rates (caused by Diarrhea)	$442*10^{-5}$

Source: (WHO, 2004)

According to the Beijing's statistical yearbook of 2004, the registered permanent residence in Beijing is 12 million, of which 2.25 million people live in the central districts. The pathogen exposures are different for residents living in central districts and living in peripheral districts. The disease burden is also different in the two types of areas. So only the population of the central districts is taken into the consideration. Secondly the proportion of population infected by the green area irrigation could be represented by the ratio of reused water amount for green area irrigation and the total wastewater amount.

Through the “Willingness To Pay” method, the World Bank valuates the health cost of water pollution in China (WorldBank, 2007b), as shown in the table 7. In terms of the figure of WHO report (2004), the total estimated DALYs caused by diarrhoea disease is 5055,000 DALYs each year. So we can get the DALY cost rate shown as following.

Table 7 Health cost associated with water pollution in China, 2003 (Billion Yuan)

Disease	**Morbidity cost**	**Mortality cost**
Diarrhoea	0.22	14

Source: (WorldBank, 2007b).

DALY cost rate
=Total health cost / DALY amount in China

2.2.4 Economic benefit

If there would be no on-site project, reused water would be transferred to the users from the big centralized water recycling plant. In a centralized system constructing pipes is a big issue. Pipe construction needs large amount of investments and lots of input on the work of demolition and relocation. So decentralized systems save these investments. Thus the avoiding costs of constructing pipes could be regarded as a social benefit of decentralized water recycling system.

The benefit of avoiding the constructing of pipes can be estimated by finding the water transferring distance between a closest centralized plant and the Qing residential area, and the unit cost spent on the pipes. There are in total five big centralized plants in Beijing: Gao beidian, Fang zhuang, Wu jia cun, Qing he and Jiu xianqiao. It is easy to find in the figure 9 that the Fangzhuang water recycling plant is the closest one to the Qing project. We assume that the reused water of Qing residential area could be provided by the Fangzhuang plant if there is no Qing project. The distance between Fangzhuang project and the Qing residential area is at least 8 km. That means at least 8 km pipes would be constructed to transfer the reused water from the centralized system if there would be not Qing project.

According to interviews with officials of the Beijing drainage group, the cost for pipe construction is between 2000 Yuan/m and 20,000 Yuan/m (Beijing Daily, 2006). Since the pipe would have to be built in the existing urban area, demolition and relocation are unavoidable. As a result the cost of pipe construction for reused water distribution is extremely high.

Avoiding cost of constructing pipes

= unit cost × estimated distance

2.2.5 Environmental benefit

The principal environmental benefit of water recycling system is water resource saving. More and more “new water” is created through reusing the wastewater, and the stress of water resource depletion could be released accordingly. The production of reused water per year could be regarded as the water resource saving amount in each year.

The water price of Beijing is 3.7 Yuan per cubic meter, of which 1.1 Yuan is a water resource fee, and 1.7 Yuan is a municipal water treatment fee, while 0.9 Yuan is the wastewater treatment cost. So in this paper, 1.1 Yuan is regarded to be the unit value of water resource. The environmental benefit can then be calculated.

The principal environmental benefit of the BNU project is water resource saving. The BNU project produces around 150,000 m^3 per year. And the water resource price is 1.1 yuan/ m^3 in Beijing.

2.2.6 Social benefits

Asano and Anderson both accepted that there are social benefits from water recycling and reuse (Anderson, 1996; Asano, 2005). The decentralized project could benefit to improve people’s awareness of water saving and help introducing a new water culture.

Normally the awareness improvement could be reached through all kinds of public education and advertisement. As decentralized system could help to improve the people’s awareness, it saves the money on the education input. So the money saved is assumed to be a social benefit from the decentralized project.

According to the statistical data of the Department of Planning and Programming(DPP, 2001), the average investment on education and research in water sector in Beijing is 2,780,000 Yuan. We assume that the educational effect of a decentralized plant is the same as the effect of public education. So the educational expenditure can be calculated through the population percentage.

The BNU project could benefit to improve the social awareness of all staff and students on water saving. This could be regarded as the expense saving on education on raising social awareness. The total population of the Beijing Normal University is 35,000. According to the statistic data of the department of planning and programming, the average investment on education and research in water sector in Beijing is 2,780,000 yuan.

So the saving on educational expenditures
= total spent on waster saving education /total population * population affected by BNU project

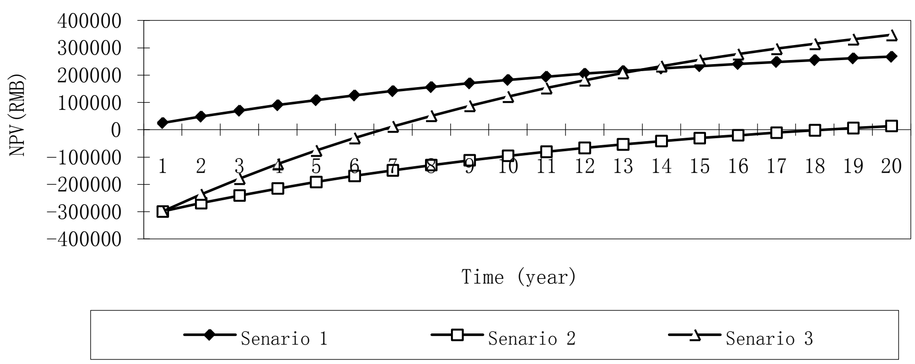
2.3 Measures for comparative analysis

2.3.1 The NPV

Figure 18 below shows the comparison of the NPV values for the three options during the evaluation period. Both option 2 and option 3 represents the situation of "change", and the option 1 represents the situation of "no change". Because there is no initial investment in the Option 1, the NPV of senario1 is always larger than zero. The duration of time when the net benefit compensates for the total investment is the capital recovery period. The capital recovery period of the option 3 is 6 years, but the capital recovery year of the option 2 is relatively longer, 19 years. Compared with "no change", obviously the option 2 is not a good option. The NPV value of the option 2 is always negative during the estimated period. It means that it is not economically feasible to build the rainwater harvesting system if there is not subsidy or other incomes to recovery the cost. The yields of four kinds of crops are too small to cover the cost of the system.

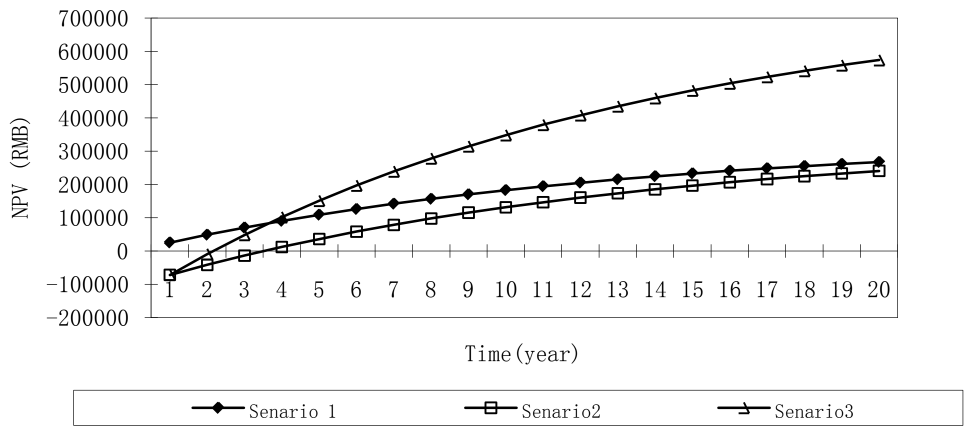
However, the situation could become better if using the storage for mushroom planting. In the option 3, it only takes 6 years to recovery the cost. At the 14th year, the NPV of the option 3 is almost same to the option 1. After then, the NPV of the option 3 has higher value than that of the option 1. Mushroom planting helps to increase the total profit so that the option 3 is economic feasible. But it will take 14 years to make the net benefit to reach the level of "no change" situation. The period of 14 years seems to be too long time. The peasants may prefer to keep the "no change" situation rather than engaging in this project.

Figure 7 Comparison of three options without subsidies



Generally the project of rainwater harvesting could be subsidized by the government and related institutes. The An project obtained a total of 70% subsidies and the project manager just pays 30% of the initial investment, which is around 105,000 yuan. If we consider the subsidies as a benefit to the project manager, the initial investment cost will become 105,000 yuan. Then the evaluation result will be changed as shown in the figure 19 below. Apparently the option 3 is still the best option as it just takes two years to recover the initial cost. After 4 years, its NVP value starts to take over the option 1 and grows faster. If there is not mushroom planting, the cost recovery period could become four years. Although the option 2 becomes to be economic feasible under the condition of financial subsidies, its NPV line is still below than the option1. The difference between two options is around ten thousands yuan which is a large amount to the people living in Beijing rural area. So the option 2 is not the preference option even though it is economically feasible.

Figure 8 Comparison of three options with subsidies



The discussion above implies the availability of subsidies will affect the results of economic analysis significantly. If there is no subsidy to finance the project, the rainwater harvesting system could become a big burden for the project manager. Other sources of finance such as mushroom planting may solve the problem, but it not a preferred option. After obtaining subsidies, the project becomes economically feasible even though there is no mushroom planting. Moreover, it shortens the cost recovery period. We find that the option 3 with subsidies is the only preferred option. Mushroom planting promotes the profit making and effectively finances the rainwater harvesting system.

The three options under two different conditions: with and without subsidies. It takes net present value as the measurement for the comparison. The results reflect how difficult it is to carry out the project in the long term if there are no subsidies. The situation of “change” is not better than the situation of “no change”. However if there are subsidies, the project becomes economically feasible and the cost recovery period will become shorter. Taking subsidies and meanwhile using the storage tank for mushroom planting makes the situation of “change” better than “no change”. In this way the farmer can make sure the rainwater harvesting system will be financially sustainable.

2.3.2 IRR

The Internal Rate of Return (IRR) is chosen as the criterion for the economic evaluation, which represents the effectiveness of a project. The IRR is the interest rate that equals the present value of benefits to the present value of costs, which implies at this rate the net present value of an investment equals to zero. IRR reflects situation of the investment return during the project operational period. So the higher the IRR is, the more efficient is the project.

The equations below show the evaluation process through cost benefit analysis approach.

$$C = C_O + C_S + C_E$$

$$B = B_O + B_S + B_E$$

$$\sum_{t=0}^{t=n} \frac{B_t - C_t}{(1+\lambda)^t} = 0 \text{ ---> IRR} = \lambda$$

In the equations, C means total cost, B means total benefit. Then Co, Cs and C_E are economic cost, social cost and environmental cost. Correspondently Bo, Bs and B_E are economic, social and environmental benefits. C_t is the cost at year t, and B_t is the benefit at year t. n the time span of economic evaluation. λ is the internal rate of return.

Hypothesis 1: the internal rate of return should be larger than the social interest rate.

So, if λ > social interest rate, then the alternative system is economic feasibility,
if λ < social interest rate, then the alternative system is not economic feasibility.

2.3.3 The ratio of benefit and cost

The ratio of benefit and cost is used as the criterion for economic feasibility. So if $R_{B/C} > 1$, the project is economic feasibility. If $R_{B/C} < 1$, that means the project is not economic feasibility. Economic value of each item namely “shadow price” will be taken for the economic analysis.

$$C = C_O + C_E$$

$$B = B_O + B_S + B_E$$

$$C_{PV} = \sum_{t=0}^{t=n} \frac{C_t}{(1+r)^t}\ ;\ B_{PV} = \sum_{t=0}^{t=n} \frac{B_t}{(1+r)^t}\ ;\ R_{B/C} = \frac{B_{PV}}{C_{PV}};$$

Where, C_O: economic cost, C_E: environmental cost, C_S: social cost, B_O: economic benefits, B_E: environmental benefits, B_S: social benefits, C_{PV}: present value of cost, B_{PV}: present value of benefit, $R_{B/C}$: ratio of benefit and cost.

3. Demos in Switch project

Figure 9 The location of Qing project and BNU project

Figure 10 The location of the An project

3.1 Introduction of the Qing project

The function of the Qing project is to reclaim grey water and reuse it. The Qing project is located in a residential area in the Beijing city centre, built in 2003. It is a small scale project serving only around 2583 persons. Two workers are in charge of the project. Its initial construction costs were funded by the government so the project manager is only concerned about the operation and maintenance cost.

The reclamation plant is the main part of the project, constructed underground and besides a parking place. The depth of the plant is 8 m and its total surface is 218 m^2. Like other systems the Qing project uses a simple treatment technique. The flow chart of the wastewater reclamation is shown in the figure 11, which is designed by the institute of Chinese construction science. Besides the water reclamation plant, there are double collection pipes in the system. Wastewater is collected separately: the grey water including shower and sanitation wastewater, and the black water covering other wastewater. The grey water is recycled and reused, and the black water is transferred to the municipal sewage system.

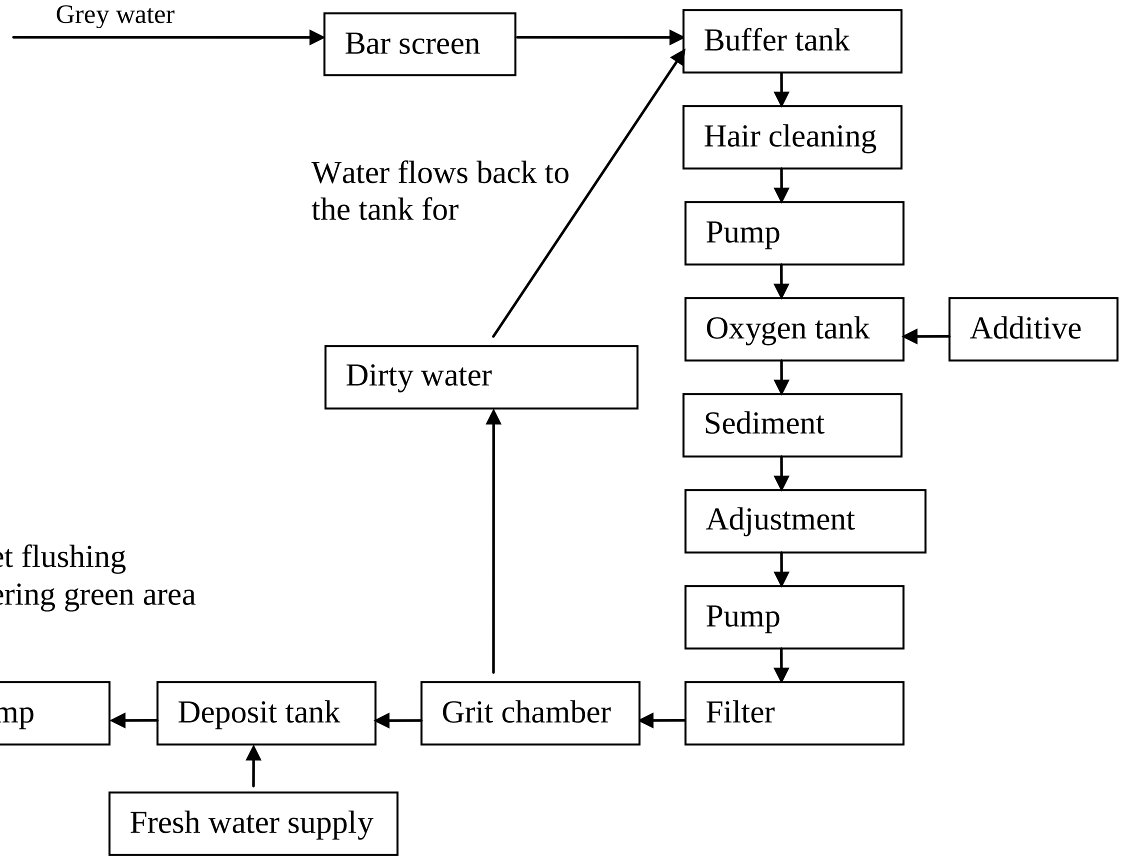
The present case studies try to evaluate the decentralized water recycling system through an economic feasibility analysis and a financial appraisal study. In the economic analysis, full cost and benefits are evaluated separately. For the evaluation of the environmental cost, the concept of DALYs is adopted for valuation of the health impact on a project.

The economic analysis indicates that the decentralized water recycling system is economic feasible. The saving of large number of pipe construction cost is the main reason for the economic feasibility. Moreover, the economic analysis proves that the decentralized system is an environmental friendly system because the environmental benefits are larger than the environmental cost.

In the opinion of government, the decentralized systems have a positive influence, but from the viewpoint of project manager, the decentralized systems have serious financial performance problems. High operation and maintenance cost and a low price for reused water are the main reasons of the system's financial non feasibility.

Although the construction of decentralized systems could save water resources and save capital investments, the decentralized systems may not continue to operate in the long term if the financial problems are not solved. Thus solving the financial problems of the decentralized systems should be a political agenda in the future (Angelakis et al., 2003) .

Figure 11 Wastewater reclamation flow chart

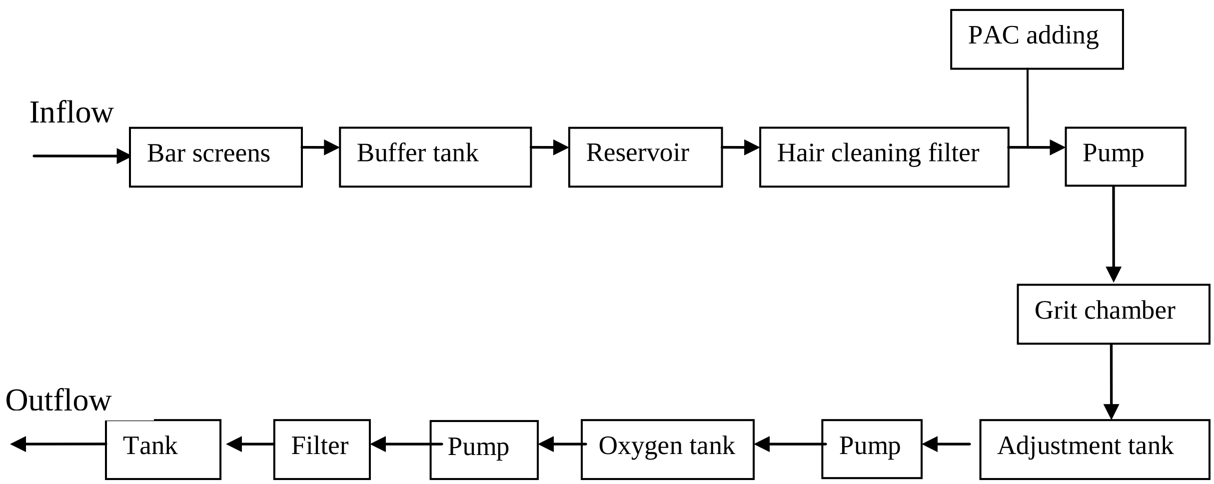


Source from interview with the manager of Qing project)

3.1.2 Introduction of the BNU project

The function of the BNU project (Beijing Normal University) is to reclaim greywater and reuse it. The BNU project also lies in the Beijing city center (Haidian district). There are almost 35000 students and staffs living in that campus, and the area of campus is 700,000 m^2 (source from BNU website). Because of the government's regulation, the Beijing Normal University has to build an own wastewater reclamation plant. The BNU project is located in the campus, built in 2002. The wastewater is collected from the public shower lounger, and the treated water is mainly reused for the toilet flushing of student accommodations and the green land irrigation. The maximum capacity of the plant is 1000 cubic meters per day, but averagely the plant treats around 400 cubic meters water each day.

Figure 12 The flow chart of plant of BNU



The figure 12 indicates the treatment process of the BNU wastewater reclamation plant, which is similar to the treatment technique of the Qing project. There are three pumps shown in the above figure. Before and after each pump are the deferent treatment processes. From the bar screens to hair cleaning filter steps, they are belongs to the preliminary treatment. These steps are to screen out and separate the debris from the wastewater. Because the wastewater is mainly from the public shower lounge, large number of hair is involved in the wastewater. Hair cleaning filter removes the hairs which may be blocked in the pipes at the latter steps. PAC is a chemical for decomposing the debris. After the first pump, it is the primary treatment process. It is separating the solid waste from the water. The adjustment tank makes the solid to settle to the bottom and then some sludge would be drawn off the bottom. Then the second treatment process is biological treatment which is removing the organic matter in wastewater. In the oxygen tank, there are pumps to keep supplying oxygen. So the microorganisms could absorb organic matter from sewage as their food supply. Finally, the water goes through final filter and enters into the tank for sedimentation. Before the stream discharge, a chlorine-neutralizing chemical would be put into the tank for removal of disease-causing organisms from wastewater.

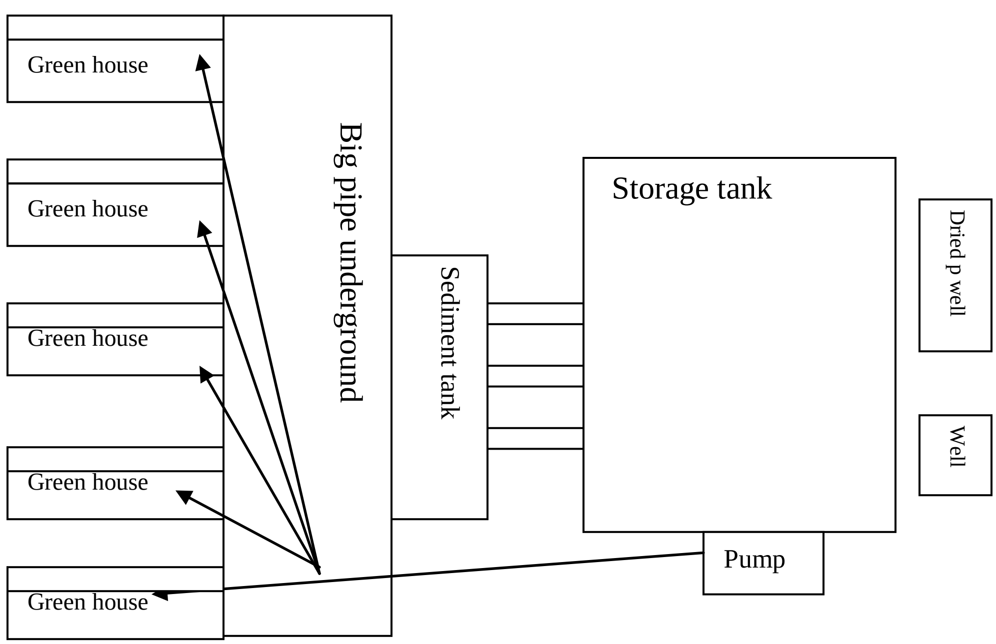
The BNU project produces water around 150,000 m^3 each year. The initial investment of the project is subsidized by the Beijing government and paid by the Beijing normal university. And the operation and maintenance cost is also paid by the Beijing normal university. Excepting the depreciation on the equipment, there is not financial loss in the BNU project. But the financial profit of the project is also zero because the yearly funding provided by the Beijing normal university is used up every year.

3.3 Introduction of the An project

The An (An Ge Zhuang village) project is promoting a household rainwater harvesting system in the rural areas of Beijing. The collected rainwater is used for agricultural irrigation. The An project is located in the Huairou district which belongs to the rural areas of Beijing. Like other farmers, the manager of the An project is facing the pressure of water scarcity, because he is living there.

There are three arguments that can prove that the selected project is a representative case. Firstly, the technique used in the An project is very similar to that of other projects in Beijing rural areas. The treatment process is designed by the same institute as used by others, the Institute of District Agricultural Science. The rainwater harvesting system of the An project consists of three main parts: catchments area, water storage and irrigation facilities. The catchment is based on five plastic covers for the green houses, in total a surface of $640m^2$. The storage tank has a capacity of around 500 m^3, which accounts for 200 m^2. The drip irrigation method is taken up by the project. It helps to save water resources for irrigation. The whole water harvesting and reuse process is shown in the figure 13. Because there is a plastic film covering the green house, rainwater goes through the plastic film down to the ditch in front of the house. Rainwater moves from the shallow ditch to the big underground pipe and then to the sediment tank. There is a filter installed in the tank. After depositing the solids, cleaned water enters the storage tank. The water is transferred from the storage tank to the green house by pump. Both the scale of system and the treatment process of the An project is similar to that of other rainwater harvesting projects in Beijing rural area (from an interview with the manager of the An project).

Figure 13 The rainwater harvest and reuse system



(Source from interview with the owner of the An project)

Secondly, the crops planted in the An project are all the common crops in Beijing is rural areas. The main agricultural fruit plantings of Beijing are apples, pears, grapes and peaches, in which the pears and grapes production accounts for respectively 18% and 5% of total fruit production (Beijing Statistic Year book 2008). Moreover, in terms of the weight measurement, vegetables production is around 45% of all crops production in Beijing. Five crops grown in the An project includes fruits and vegetables, which are grape, pear, tomato, cabbage and mushroom. Since the rainfall in Beijing is concentrated in the period from March to September, the storage tank will be idle during other periods. It is a good idea to plant mushroom in the tank when it is not used for water storage. There are two other advantages of mushroom planting: firstly mushroom requires less water, and secondly mushrooms make high net profit.

Thirdly, the financial source are similar between the An project and other projects in Beijing's rural areas. Generally these projects are constructed and subsidized by the Institute of District Agricultural Science (source from the interview with the An project manager). The An project also obtains some subsidies from the Institute of District Agriculture Science. The table 10 illustrates the distribution of investment between the stakeholders of the project. Moreover, the profit of crops is the main income to finance for the operation and maintenance of the system, which is also in the same situation as other projects.

Table 10 Investment funding distribution

Participants	**Proportion**
Project manager	30%
Chinese Academy of Science	35%
Institute of Huairou District Agricultural Science and other relevant bureaus	35%

(Source from interview with manager of the An project)

4 Financial and economic Analysis of Demo projects

4.1 The Qing project

4.4.1 Project introduction

Qingzhiyuan (Qing) project is about the water reuse system in a residential area which lies in the Xuanwu district of Beijing city. Qingzhiyuan residential area occupied 300 million m^2 with around total 1100 households. According to the <Regulation of Wastewater Reuse System Construction> (2001) issued by Beijing government, any institute whose occupying area is larger than $50000m^2$ must build the water reuse system. So like other large institutes in Beijing, Qing project have to build a wastewater reuse system.

For the restricted land area in Beijing city center, all buildings in Qing project are the high-rise apartment buildings which own on average 100 households, and totally Qing project has eleven buildings. As there was no clear policy on building the water reclamation plant before the year of 2000, some buildings constructed in the early period have not wastewater reclamation facilities. Therefore the apartments built after year 2000 have the relevant facilities, which are total seven buildings with 922 households. According to the research of Qing residential management company, only around 80% households would connect the wastewater collection pipe to the wastewater reclamation system. Therefore, the number of using water reclamation system could be 922*80%= 738 households. Normally there are 3 or 4 persons in one household (source from interview with residential management company), so the users number is about 738 households*3.5 persons/household =2583 persons.

Table 1 Relevant parameters

Item	Quantity	Unit
Total population	3227	persons
User population	2583	persons
Average reclaimed water amount	56	m^3/day
Average reused water demand	94	m^3/day
Average municipal water supplement	38	m^3/day
Water rate	3.75	yuan/ m^3
Reused water fee	1	yuan/ m^3

The reclamation plant is the main part of the project, constructed underground and besides a parking place. The depth of the plant is 8 m and its total surface is 218 m^2. Like other systems the Qing project uses a simple treatment technique. The flow chart of the wastewater reclamation is shown in the figure 11, which is designed by the institute of Chinese construction science. Besides the water reclamation plant, there are double collection pipes in the system. Wastewater is collected separately: the grey water including shower and sanitation wastewater, and the black water covering other wastewater. The grey water is recycled and reused, and the black water is transferred to the municipal sewage system.

Table 2 The progress of the treatment plant construction

Period	Process
2001	Applying to build the plant
2002	Construction is completed
2003	Equipment installation
2004	Operation test
2005	Performance

Table 3 The capacities of the main facilities

Facilities	**Capacity (m^3)**
Adjustment tank	200
Deposit tank	80
Oxygen tank	22.5
Sediment tank	10
Buffer tank	7.5

The grey water collected is around 55 m^3 per day. If the water leakage is neglected, the produced water amount could be also 55 m^3 per day. However, the actual produced reuse water can not satisfy the water requirement, so part of the “reused water” is supplemented by municipal fresh water. This is illustrated in figure 2. Almost half of the reused water is supplemented by municipal water. The produced reused water can not even satisfy the toilet flushing requirements. To simplify the calculations, we assume that the Qing project produces all the required reused water, which amounts to 1700m^3 per month.
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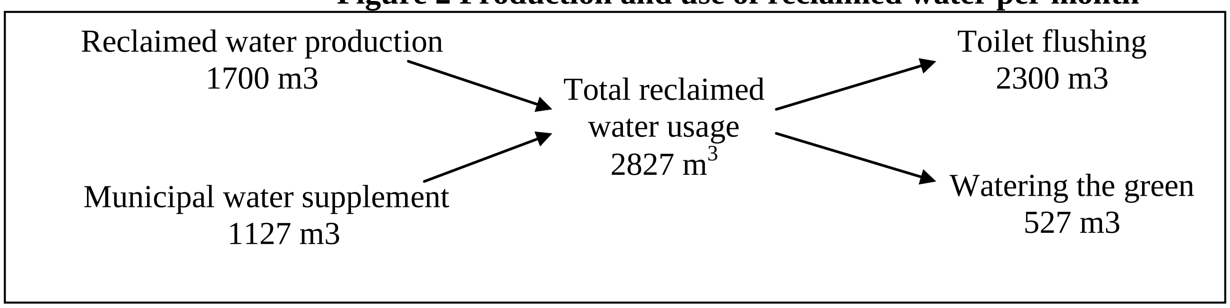
Figure 2 Production and use of reclaimed water per month



Source: from interview with the manager of Qing project

4.1.2 Methodology

4.1.2.1 Financial analysis

The income of operation should at least cover all cost of the project. Otherwise, there is no incentive for project manager to operate the system. In this part cost recovery means covering not only operation and maintenance (O&M) cost but also the construction cost. In the financial analysis, market prices are used to value all financial cost and benefits. The ratio of income and cost is the standard to testify the financial feasibility of the project. If the ratio is larger than 1, the project is financially feasible. Otherwise, the project is not financially feasible. The equations of the financial analysis are:

$$C_{PV} = \sum_{t=0}^{t=n} \frac{C_t}{(1+r)^t} \quad (1);$$

$$I_{PV} = \sum_{t=0}^{t=n} \frac{I_t}{(1+r)^t} \quad (2);$$

$$R_{I/C} = \frac{I_{PV}}{C_{PV}} \quad (3);$$

Where, C_t: financial cost occurs at period t, I_t: financial benefits occur at period t, n: evaluation period, r: discounting rate, C_{PV}: present value of financial cost, I_{PV}: present value of financial benefits, $R_{I/C}$: ratio of financial benefits and cost.

The life cycle cost analysis method is used for the financial cost analysis. It is a systematic analytical process for evaluating cost of various new designs (Durairaj et al., 2002). In terms of the model of the Fabrychy and Blanchard (1991), a cost breakdown structure should be made to specify which cost should be considered for the whole life cost. The cost breakdown structure is a way of classifying cost as a basis for assessing the life cycle cost (Fabrycky and Blanchard, 1991). The cost breakdown of this paper is shown in the table 4, which includes construction cost, operation and maintenance cost and residual values.

Table 4 Cost breakdown structure

Construction cost	**Operation and maintenance cost**	**Residual values**
Plant construction cost Pipe construction Equipment cost	Electricity Chemical Personnel Reparation Other management cost	Building Machine Pipe

In terms of the cost breakdown structure, the values of construction cost, O&M cost and residual values are indicated in the table 2. About the residential values, three parts are considered: building, machine, and pipe. The residual values are the values left after the depreciation of the materials. A linear depreciation method is used, which is presented by the equation 4.

$$V_r = V_o \times (1 - \frac{Y_t}{Y}) \quad (4);$$

Where, V_r : residual value, V_o : original value, Y_t : used time, Y: total life time.

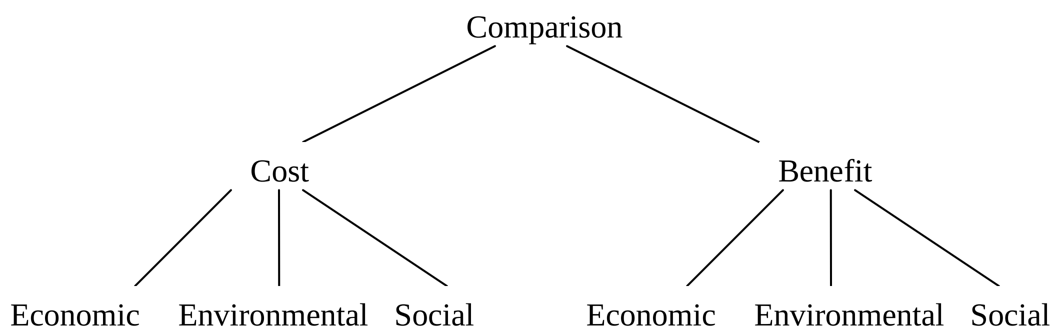
We assume the life time of the project is 10 years in total. According to <Chinese Economic Evaluation Parameters on Construction>, generally the construction buildings in the water sector can be used for 50 years. The machine could be expected to be used for 15 years (from the interview with the producer of the equipment). The pipes are assumed to be used for 15 years without any replacement or repairs.

The financial benefits of a project are represented by the income of the project, including water charges and subsidises. The water charge amount depends on the reused water rate and reused water production. The rate paid for reused water is 1 Yuan/m^3 in Beijing. It has not changed for years. The rate is assumed to be at the same level during the period of consideration.

4.1.2.2 Economic analysis

From the view point of government, it is significant to evaluate the comprehensive influence caused by the decentralized systems. The influence includes the internal and external impacts such as the social and environmental impacts. Hence we will identify and valuate the full cost and benefit of the project using cost-benefit analysis method. The framework of cost and benefit is presented in the figure 3, indicating the inclusive of cost and benefit to be valuated. For the cost estimation, economic and environmental costs are considered, and the environmental cost converts health impact and noise impact. For the benefit estimation, economic, environmental and social benefits are all taken into valuation. After the valuation of each cost and benefit item, a comparison between cost and benefit is implemented in order to exanimate the economic feasibility of the project.

Figure 3 The analytical framework for the economic analysis



The table 1 below specifies the economic cost. The initial investments of the Qing project were subsidized by the government. Hence the government paid for the land, the construction and the equipment, in total 780,000 Yuan. The project paid for the network installation costing 4,000,000 Yuan. Total investments are considered in the present paper.

Table 5 Classification of the economic cost

Construction Cost	Government: Land, Building construction fee, Costs of equipment Project: Network installation: pipes fee and sewage facilities Total 4,780,000 Yuan
Maintenance and Operation Cost	Electricity, Chemical Cost, Personnel cost: salary and training, Reparation, Network maintenance (such as leakage mitigation, pump maintenance, pipe cleaning)

Economic cost
= construction cost + O&M cost
= 5,211,000 Yuan (one US dollar is 6.5 Yuan)

The total economic cost is 5.2 million Yuan, of which the initial investment is total 4.8 million Yuan and the O&M is 0.04 million Yuan per year. Figure 4 describes the distribution of construction cost. The initial construction cost includes the plant construction cost, pipe building cost, design cost and equipment installation cost. Obviously, pipe constructing cost has the largest area in the pie below, which accounts 83% of total construction cost.

Figure 4 The distribution of construction cost

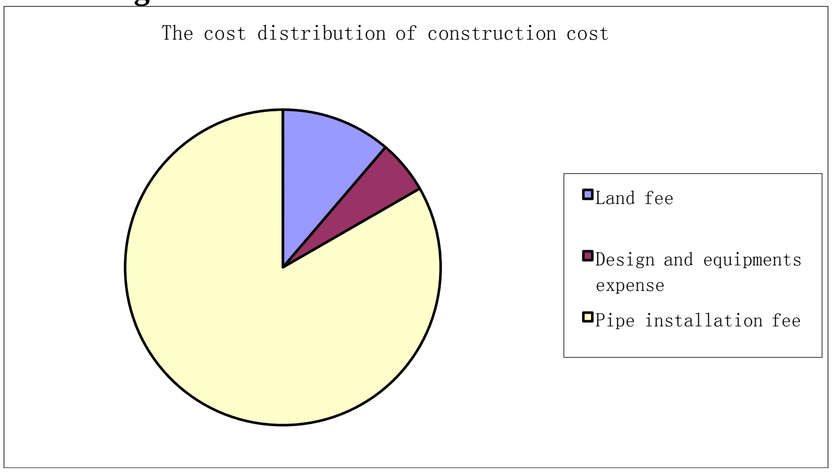
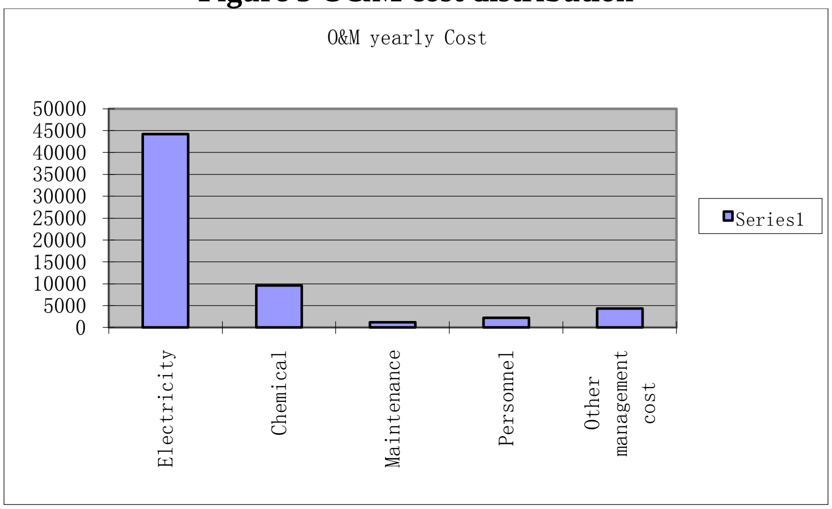


Figure 5 O&M cost distribution



The categories of O&M cost is shown in the figure 5. Apparently electricity cost is the main expense and much higher than the other O&M costs. The electricity consumption each year is around 63,167 Kwh and the price of electricity in Beijing is 0.7 Yuan/ Kwh. The electricity consumption is fixed, depending on the plant's capacity. Hence the unit price of electricity strongly affects total O&M cost. The cost of chemicals is the second highest expense in the O&M cost.

Even though the plant of the Qing project is located underground, it still makes a lot of noise and affects the resident's living negatively. Around 10 households of the Qing residents are affected by the noise as their apartments are close to the plant. This noise causes an environmental pollution to the Qing resident.

Similar to the health impact, there is not direct market price for noise effects. Few papers evaluate the noise pollution in China, and the existing studies mostly make evaluation in the national and regional level. For example, Wen and Chen estimates the noise pollution of China, and Liu valuates the noise pollution in Dalian city (Liu, 1999; Wen and Chen, 2007). For simplifying the determination, the current paper would make the valuation of the noise impact of the Qing project through converting the value of Dalian city into the value for Beijing. Wen and Chen (2007) also take the method of conversing Liu (1999)'s result into the noise pollution of China (Liu, 1999).

The noise pollution cost of Dalian city could be converted to Beijing's noise pollution cost according to average income and consumption difference between Dalian and Beijing city. Liu estimates the noise pollution in Dalian city through the method of Willingness To Pay (Liu, 1999). He finds that the estimated households who live in the high decibels areas, namely 66-70 decibels, would like to pay average 26 Yuan /month to eliminate the noise. So the noise pollution cost in Dalian could be regarded as around 26 Yuan/household each month. According to Beijing statistic yearbook 2005, the average income of Beijing's resident is 1.5 times more than the income of Dalian's people. Additionally the ratio of the average consumption amount between Beijing and Dalian is also 1.5. So we assume all kinds of costs in Beijing are 1.5 times more than the costs of Dalian city. Moreover, the noise of the Qing plant is assumed to be 66-70 decibels which is the same to the noise level of the study of Liu. Thus the noise impact of the Qing project could be obtained. The equation below indicates the process of estimation.

Table 6 The income and consumption comparison between Beijing and Dalian city

	Beijing city	Dalian city	Ratio
Income (capita•year)	15637.8 Yuan	10377.8 Yuan	1.5
Consumption (capita•year)	12200.4 Yuan	7759.9 Yuan	1.5

Source: Beijing statistic yearbook (2005).

Noise impact
=Cost per household × affected household amount ×12 months
= 26×1.5 ×10 ×12
= 4680 Yuan /year

The Qing project provides non-potable water for toilet flushing and green lands irrigation. It is often thought by the engineers that the non-potable recycling water has no negative impact on human health because the amount of pathogens in the recycling water is very small. However human health risks depend on the source of the pathogens, the treatment applied and the exposure route (Ottoson and Stenström, 2003). It means the treatment process and exposure route could also become the causes of health risk. In Beijing, there are no standard techniques for the recycling of water process, so each wastewater recycling plant has its unique technique. Even though the water quality reaches the regulated standard for recycling water, there is still a certain amount of bacteria in the water. Moreover, the "surface irrigation technique" could be negative to the health risk (Christova-Boal et al., 1996). The Qing project uses the "spraying irrigation technique", which is a typical surface irrigation method. As a result, the pathogen in the recycling water may be left on the grass, and then transfer to the residents who come in contact with the grass, and may finally lead to epidemic diseases. The current study assumes that the non-standard wastewater treatment process and surface irrigation method may cause health risks in the Qing project. The present paper would determine the increase of health risks after the construction of a water recycling plant using the water for irrigation.

Valuation of health impact is very complicated because there are no direct market prices for human mortality and morbidity. Economists try to solve these problems through determining the value of statistical life, willingness to pay, and adjusted human capital. These methods are the principal economic methods for valuing the health impact. Because of limitations, these economic methods have to be applied to big samples with a large amount of data. In the literature the valuation of health risk is calculated at the national or regional level (Zhang, 2002). Valuing the environmental health impact at the level of one project is a neglected issue. The present paper would adopt the indirect valuation method to assess the health impact from a small wastewater recycling plant.

For the purposes of this study, Disability Adjusted Life Year (DALY) is taken as a measurement unit for the impact on human health. DALY is an index of health risk, developed by the World Health Organization (WHO) and the World Bank (Murray and Lopez, 1997; Zhang, 2002). DALY is a method to measure the disease burden, which considers the impacts of life loss caused by death, healthy life loss caused by deformity after disease, and healthy life years (WHO, 2005). It is the sum of discounted and age-weighted years of life lost. One DALY corresponds to one lost year of healthy life, and the burden of diseases to the gap between current health status and an ideal situation where everyone lives until old age, free of diseases and with no disabilities (WHO, 2007). DALY is used in many studies for measuring the health risk. For example, (Aramaki et al., 2006) find that after building the wastewater treatment, the disease burden of a community changed from 60 DALYs per year to 5.7 DALYs per year. In this study, DALY is a bridge to convert the monetary value of health risk from national level to the scope of a small project. Moreover, diarrhoea disease is estimated to be the largest contributor to the burden of water-related disease(OECD, 2007). Many papers limit the evaluation to diarrhoea disease risk (OECD, 2007; WHO, 2007; WorldBank, 2007b) while there are other microbial contaminations included in water pollution. The present study also focuses on health risk related to the diarrhoea disease risk. Therefore, the health risk can be determined by multiplying the DALY number of diarrhoea risk caused by the project and the DALY cost rate.

The figures in table 3 are estimated by the WHO (2004) and are based on the information provided by China concerning the levels of child mortality (between the ages of 0 and 5) in an earlier time period and adult mortality (between the ages of 15 and 60). The age-standardized DALY rate means the standard DALYs with age-weighting and time discounting. Because both child and adult with different ages are involved in the estimation, it is more precise to use the age-standardized DALYs rate: $442*10^{-5}$ DALYs per person for the evaluation. OECD finds that 88% diarrhea disease is attributed to water and sanitation (OECD, 2007). Thus the DALY rate of diarrhea disease due to water pollution is $442\times10^{-5} \times 0.88= 389*10^{-5}$ DALY/person. Since Beijing has the highest diarrhea incidence, the average DALY rate of China could be regarded as the DALY rate of Beijing.

Table 7 The DALYs in China (population: 1302,307,000)

Total DALY number (caused by all diseases)	200,273,000
DALY number (caused by Diarrhea)	5055,000
Age- standardized DALY rates (caused by Diarrhea)	$442*10^{-5}$

Source: (WHO, 2004)

According to the Beijing's statistical yearbook of 2004, the registered permanent residence in Beijing is 12 million, of which 2.25 million people live in the central districts. The pathogen exposures are different for residents living in central districts and living in peripheral districts. The disease burden is also different in the two types of areas. So only the population of the central districts is taken into the consideration. Secondly the proportion of population infected by the green area irrigation could be represented by the ratio of reused water amount for green area irrigation and the total wastewater amount, which is 8%. Thirdly the proportion of the green land area between the Qing project and Beijing city center is 0.09%.

DALYs number
=DALY rate × population × percentage of population infected by irrigation × percentage of impact of the Qing project
$= 389 /10^5 \times 22.5 \times 10^5 \times 8\% \times 0.09\ \%$
= 0.7 DALY/year

Through the "Willingness To Pay" method, the World Bank valuates the health cost of water pollution in China (WorldBank, 2007b), as shown in the table 4. In terms of the figure of WHO report (2004), the total estimated DALYs caused by diarrhoea disease is 5055,000 DALYs each year. So we can get the DALY cost rate shown as following.

Table 8 Health cost associated with water pollution in China, 2003 (Billion Yuan)

Disease	**Morbidity cost**	**Mortality cost**
Diarrhoea	0.22	14

Source: (WorldBank, 2007b).

DALY cost rate
=Total health cost / DALY amount in China
= $(14+0.22) \times 10^9 / 5055{,}000$
= 2813 Yuan/DALY

So the health impact of the Qing project can be calculated finally as following.

Valuation of health impact
= DALY cost rate × DALYs number
= 2813 * 0.7
= 1969 Yuan /year

If there would be no Qing project, reused water would be transferred to the Qing residential area from the big centralized water recycling plant. In a centralized system constructing pipes is a big issue. Pipe construction needs large amount of investments and lots of input on the work of demolition and relocation. So decentralized systems save these investments. Thus the avoiding costs of constructing pipes could be regarded as a social benefit of decentralized water recycling system.

The benefit of avoiding the constructing of pipes can be estimated by finding the water transferring distance between a closest centralized plant and the Qing residential area, and the unit cost spent on the pipes. There are in total five big centralized plants in Beijing: Gao beidian, Fang zhuang, Wu jia cun, Qing he and Jiu xianqiao. It is easy to find in the figure that the Fangzhuang water recycling plant is the closest one to the Qing project. We assume that the reused water of Qing residential area could be provided by the Fangzhuang plant if there is no Qing project. The distance between Fangzhuang project and the Qing residential area is at least 8 km. That means at least 8 km pipes would be constructed to transfer the reused water from the centralized system if there would be not Qing project.

According to interviews with officials of the Beijing drainage group, the cost for pipe construction is between 2000 Yuan/m and 20,000 Yuan/m (Beijing Daily, 2006). Since the pipe would have to be built in the existing urban area, demolition and relocation are unavoidable. As a result the cost of pipe construction for reused water distribution is extremely high. In the current paper, we take the least unit cost value 2000 Yuan/meter and the shortest distance value: 8 km for the estimation.

Avoiding cost of constructing pipes
= unit cost × estimated distance
= 16,000,000 Yuan

Figure 6 The location of Beijing centralized water reclamation plants

The principal environmental benefit of water recycling system is water resource saving. More and more “new water” is created through reusing the wastewater, and the stress of water resource depletion could be released accordingly. The production of reused water per year could be regarded as the water resource saving amount in each year.

The water price of Beijing is 3.7 Yuan per cubic meter, of which 1.1 Yuan is a water resource fee, and 1.7 Yuan is a municipal water treatment fee, while 0.9 Yuan is the wastewater treatment cost. So in this paper, 1.1 Yuan is regarded to be the unit value of water resource.
The environmental benefit
= unit value × reused water amount
= 22440 Yuan / year

Asano (2005) and Anderson (1996) both accepted that there are social benefits from water recycling and reuse (Anderson, 1996; Asano, 2005). The decentralized project could benefit to improve people’s awareness of water saving and help introducing a new water culture.

Normally the awareness improvement could be reached through all kinds of public education and advertisement. As decentralized system could help to improve the people’s awareness, it saves the money on the education input. So the money saved is assumed to be a social benefit from the decentralized project.

According to the statistical data of the Department of Planning and Programming(DPP, 2001), the average investment on education and research in water sector in Beijing is 2,780,000 Yuan. We assume that the educational effect of a decentralized plant is the same as the effect of public education. So the educational expenditure can be calculated through the population percentage.

Savings on educational expenditures
=Total spent on water saving education / total population × population of Qing project
= 2780,000 / 22.5 $\times 10^5 \times$2583
=3191 Yuan/year

4.1.23 Cost-benefit comparison

After valuating the full benefits and cost items, the present values of cost and benefits can be evaluated. The following equations represent the valuation process. C_O means economic cost and C_E is environmental cost. B_O denotes the economic benefits, B_E denotes the environmental benefits and B_S denotes the social benefits. According to the publication <Chinese Economic Evaluation Parameters on Construction> (2006), the discount rate for the study is 8% including the inflation rate of China. Because few plants are operational for a long period in Beijing, the evaluation period is assumed to be 10 years. The plant's operation is assumed to be at the same level during the period considered, which means the consumption of energy and chemical would be the same during the year.

The comparison between cost and benefit could be presented through the ratio of benefit and cost, $R_{B/C.}$ The result is used as the criterion for economic feasibility. So if $R_{B/C} > 1$, the project is economic feasibility. If $R_{B/C} < 1$, that means the project is not economic feasibility.

$$C = C_O + C_E$$

$$B = B_O + B_S + B_E$$

$$C_{PV} = \sum_{t=0}^{t=n} \frac{C_t}{(1+r)^t} = 5{,}300{,}000 \text{ Yuan}$$

$$B_{PV} = \sum_{t=0}^{t=n} \frac{B_t}{(1+r)^t} = 16{,}230{,}000 \text{ Yuan}$$

$$R_{B/C} = \frac{B_{PV}}{C_{PV}} = 3$$

4.1.3 Discussion

The result of the economic analysis reveals that the ratio of benefit and cost $R_{B/C}$ is larger than 1, which implies that the Qing project is economically feasible. It is reflected in the figure 7 that the economic cost and social benefit are the crucial factors in the economic analysis because both of the columns are higher than others. Though the social benefits consist of avoiding costs of constructing pipes and the saving of raising social awareness, avoiding cost of pipe construction is the main part of the social benefit, which is even larger than the total cost. The pipe constructing cost is 16 million Yuan, and the initial investment of the Qing project including pipe construction cost is only 4.8 million Yuan. That means the funding of the distribution pipes for centralized plant could finance the investments of around 4 decentralized plants.

We made the calculation on the environmental impact of the Qing project. The result shows that the environmental cost only account for 0.6% the total cost, and similarly the percentage of the environmental benefit of the total benefit is 0.7%. It seems that the environmental factor has no significant effect on the result of economic analysis. However, the crucial point is that the value of environmental benefit is around 3.4 times the environmental cost. It proves that the decentralized system is relatively environmentally friendly although it causes a negative health impact and noise pollution.

Economic feasibility is not equal to financial feasibility. The financial appraisal result reflects that the present value of the cost is almost 25 times more than the present value of revenue so the ratio of revenue and cost is only 0.04. It means that the project is financial non feasibility. The project manager was losing money from the beginning of the functioning of the system. So in the opinion of the project manager, the construction of decentralized system is not a good decision. The financial non feasibility may be explained by two points: high operation cost and a low price of reused water.

Figure 7 The comparison between cost and benefit

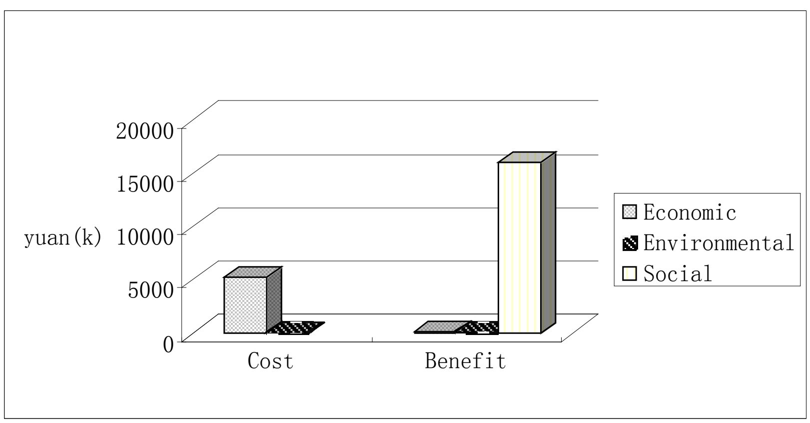


Table 9 Final economic and financial analysis result

Economic feasibility	**Financial feasibility**
C_{PV}= 5,300,000 Yuan	C_{PV} = 2,776,000 Yuan
B_{PV}= 16,230,000 Yuan	I_{PV} = 101,000 Yuan
$R_{B/C}$= 3	$R_{I/C}$= 0.04
Feasibility: Yes	Feasibility: No

The high operation and maintenance (O&M) cost may be caused by the scale effect. The unit O&M cost of the Qing project is 4.3 yuan/m^3, but the unit cost of the centralized project (Gao beidian project) is only 0.35 yuan/m^3 (Zhang et al., 2007). Due to scale economies (Yamagata et al., 2003; Friedler and Hadari, 2006) the centralized plant has much lower O&M cost than the decentralized plant. Moreover, scale effects could be reflected in the comparison between the Qing project and other projects. Liu *et al.* (2003) make the estimation of the cost of a decentralized water reuse plant of Beijing Normal University under the standard conditions (Liu et al., 2003). Hence its estimated cost could be regarded as the parameter to be compared with the Qing project. The technique of wastewater treatment process of the Qing project is similar to that of the system of Beijing Normal University, so it is reasonable to make comparison between these two projects. The result of the table 8 indicates that the unit cost of the Qing project are 2.7 times the unit cost of Beijing Normal University while the capacity of the Qing project is one tenth of the compared system.

The cost item of "other management cost" could be another reason for the high operational cost. It comprises the executive cost and business operational cost. Few of papers take this item into consideration when evaluating the O&M cost. For example, this kind of cost is not included in the studies of Liu *et al.* (Liu et al., 2003) and Jia *et al.* (Jia et al., 2005). This is indirect but important cost item which few researchers include it into their analysis. The "other management cost" account for 70% of the total O&M cost, which should not be neglected in the economic analysis.

Table 10 The comparison between Qing project and standard parameter

Item	Qing project	Beijing Normal university	Ratio
Capacity	65 m^3/day	600m^3/day	0.1
Electricity	63,167 Kwh/year 44217 Yuan/year	248,200 Kwh/year 173740 Yuan/year	0.25
Chemical	9600 Yuan/year	32400 Yuan/year	0.29
Maintenance	1200 Yuan/year	18000 Yuan/year	0.1
Personnel	2260 Yuan/year	2400 Yuan/year	1
Other management cost	4320 Yuan/ year	0	∞
Total cost	61597 Yuan/year	226,540 Yuan/year	0.27

*The electricity is calculated in terms of the unit price of 0.7 Yuan / Kwh.

The value of 1 Yuan/ m^3 is the price of reuse water, while the unit O&M cost of Qing project is 4.3 yuan/m^3. Jia *et al.* estimates the unit cost of decentralized system with the standard condition is around 2 yuan/m^3 (Jia et al., 2005), which is also higher than 1 yuan/m^3. For certain decentralized systems like the Qing project, the revenue is the only financial source for operation and maintenance. Too low reuse water price can cause financial shortage so as to hinder the sustainable performance of the system.

4. 1.4 Conclusions

The present paper tries to evaluate the decentralized water recycling system through an economic feasibility analysis and a financial appraisal study. In the economic analysis, full cost and benefits are evaluated separately. For the evaluation of the environmental cost, the concept of DALYs is adopted for valuation of the health impact on a project.

The economic analysis indicates that the decentralized water recycling system is economic feasible. The saving of large number of pipe construction cost is the main reason for the economic feasibility. Moreover, the economic analysis proves that the decentralized system is an environmental friendly system because the environmental benefits are larger than the environmental cost.

In the opinion of government, the decentralized systems have a positive influence, but from the viewpoint of project manager, the decentralized systems have serious financial performance problems. High operation and maintenance cost and a low price for reused water are the main reasons of the system's financial non feasibility.

Although the construction of decentralized systems could save water resources and save capital investments, the decentralized systems may not continue to operate in the long term if the financial problems are not solved. Thus solving the financial problems of the decentralized systems should be a political agenda in the future (Angelakis et al., 2003) .

4.2 The BNU project

4.2.1 Project introduction

Beijing Normal University (BNU) lies in the Beijing city center (Haidian district). There are almost 16000 full-time students living in that campus, and the area of campus is 700,000 m2 (source from BNU website). Because of the government's regulation, BNU has to build an own wastewater reclamation plant. The wastewater is sourced from the residential water use of the student and the public shower lounger, and the treated water is mainly reused for the toilet flushing. Only the system of the new student accommodations is connected with the wastewater treatment plant. Below the figure 8 indicates the treatment process of the BNU wastewater reclamation plant. The function of the BNU project (Beijing Normal University) is to reclaim greywater and reuse it. The BNU project also lies in the Beijing city center (Haidian district). There are almost 35000 students and staffs living in that campus, and the area of campus is 700,000 m2 (source from BNU website). Because of the government's regulation, the Beijing Normal University has to build an own wastewater reclamation plant. The BNU project is located in the campus, built in 2002. The wastewater is collected from the public shower lounger, and the treated water is mainly reused for the toilet flushing of student accommodations and the green land irrigation. The maximum capacity of the plant is 1000 cubic meters per day, but averagely the plant treats around 400 cubic meters water each day.

The figure 12 indicates the treatment process of the BNU wastewater reclamation plant, which is similar to the treatment technique of the Qing project. There are three pumps shown in the above figure. Before and after each pump are the deferent treatment processes. From the bar screens to hair cleaning filter steps, they are belongs to the preliminary treatment. These steps are to screen out and separate the debris from the wastewater. Because the wastewater is mainly from the public shower lounge, large number of hair is involved in the wastewater. Hair cleaning filter removes the hairs which may be blocked in the pipes at the latter steps. PAC is a chemical for decomposing the debris. After the first pump, it is the primary treatment process. It is separating the solid waste from the water. The adjustment tank makes the solid to settle to the bottom and then some sludge would be drawn off the bottom. Then the second treatment process is biological treatment which is removing the organic matter in wastewater. In the oxygen tank, there are pumps to keep supplying oxygen. So the microorganisms could absorb organic matter from sewage as their food supply. Finally, the water goes through final filter and enters into the tank for sedimentation. Before the stream discharge, a chlorine-neutralizing chemical would be put into the tank for removal of disease-causing organisms from wastewater.

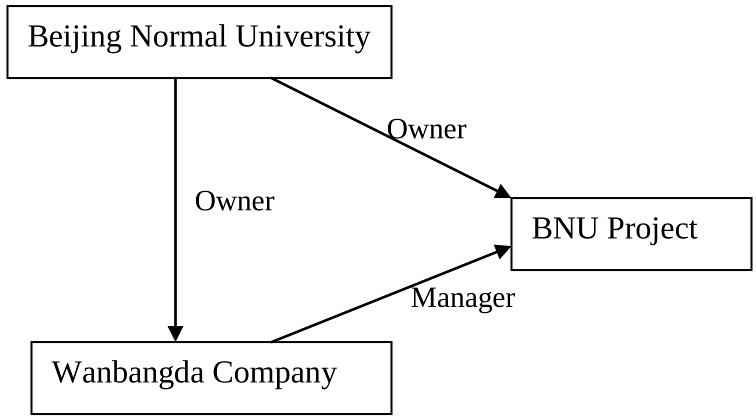
The BNU project produces water around 150,000 m^3 each year. The initial investment of the project is subsidized by the Beijing government and paid by the Beijing normal university. And the operation and maintenance cost is also paid by the Beijing normal university. Excepting the depreciation on the equipment, there is not financial loss in the BNU project. But the financial profit of the project is also zero because the yearly funding provided by the Beijing normal university is used up every year.

Three main stakeholders, Beijing normal university, Wanbangda Company and Beijing municipal government, are involved into management of the BNU project. The functions of there stakeholders are listed in the table 1. The Wanbangda Company is the project manager, who is in charge of building, operating and maintaining the project. The owner of the project is the Beijing normal university who pay for all expense of the project. Additionally, the Wanbangda Company belongs to the Beijing normal university. The relation between the Wanbangda Company and Beijing normal university determines the financial status of the BNU project.

Table 11 The function of main stakeholders

Stakeholder	Function
Wanbangda Company	Construction, operation and maintenance
Bejing Normal University	Afford all required payments
Beijing municipal government	Supervising

Figure 9 The relation between BNU, Wanbangda company and project



4.2.2 Methodology

4.2.2.1 Financial analysis

The income of operation should at least cover all cost of the project. Otherwise, there is no incentive for project manager to operate the system. In this part cost recovery means covering not only operation and maintenance (O&M) cost but also the construction cost. In the financial analysis, market prices are used to value all financial cost and benefits. The ratio of income and cost is the standard to testify the financial feasibility of the project. If the ratio is larger than 1, the project is financially feasible. Otherwise, the project is not financially feasible. The equations of the financial analysis are:

$$C_{PV} = \sum_{t=0}^{t=n} \frac{C_t}{(1+r)^t} \quad (1);$$

$$I_{PV} = \sum_{t=0}^{t=n} \frac{I_t}{(1+r)^t} \quad (2);$$

$$R_{I/C} = \frac{I_{PV}}{C_{PV}} \quad (3);$$

Where, C_t: financial cost occurs at period t, I_t: financial benefits occur at period t, n: evaluation period, r: discounting rate, C_{PV}: present value of financial cost, I_{PV}: present value of financial benefits, $R_{I/C}$: ratio of financial benefits and cost.

The life cycle cost analysis method is used for the financial cost analysis. It is a systematic analytical process for evaluating cost of various new designs (Durairaj et al., 2002). In terms of the model of the Fabrychy and Blanchard (1991), a cost breakdown structure should be made to specify which cost should be considered for the whole life cost. The cost breakdown structure is a way of classifying cost as a basis for assessing the life cycle cost (Fabrycky and Blanchard, 1991). The cost breakdown of this paper is shown in the table 1, which includes construction cost, operation and maintenance cost and residual values.

Table 12 Cost breakdown structure

Construction cost	**Operation and maintenance cost**	**Residual values**
Plant construction cost Pipe construction Equipment cost	Electricity Chemical Personnel Reparation Other management cost	Building Machine Pipe

In terms of the cost breakdown structure, the values of construction cost, O&M cost and residual values are indicated in the table 2. About the residential values, three parts are considered: building, machine, and pipe. The residual values are the values left after the depreciation of the materials. A linear depreciation method is used, which is presented by the equation 4.

$$V_r = V_o \times (1 - \frac{Y_t}{Y}) \quad (4);$$

Where, V_r : residual value, V_o : original value, Y_t : used time, Y: total life time.

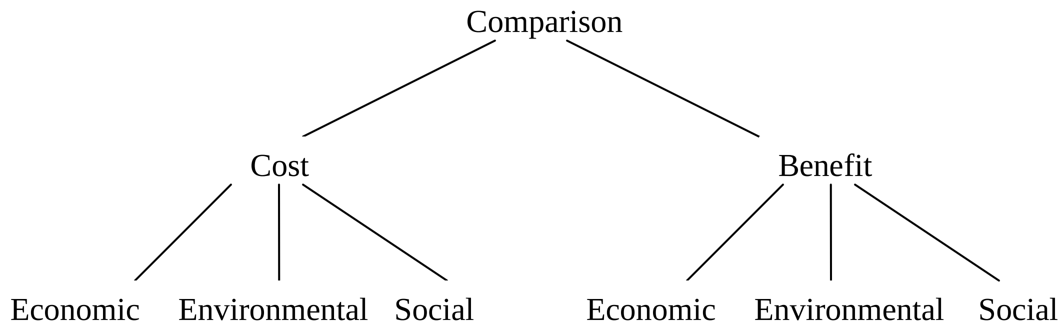
We assume the life time of the project is 10 years in total. According to <Chinese Economic Evaluation Parameters on Construction>, generally the construction buildings in the water sector can be used for 50 years. The machine could be expected to be used for 15 years (from the interview with the producer of the equipment). The pipes are assumed to be used for 15 years without any replacement or repairs.

The financial benefits of a project are represented by the income of the project, including water charges and subsidises. The water charge amount depends on the reused water rate and reused water production. The rate paid for reused water is 1 Yuan/m^3 in Beijing. It has not changed for years. The rate is assumed to be at the same level during the period of consideration.

4.2.2.2 Economic analysis

From the view point of government, it is significant to evaluate the comprehensive influence caused by the decentralized systems. The influence includes the internal and external impacts such as the social and environmental impacts. Hence we will identify and valuate the full cost and benefit of the project using cost-benefit analysis method. The framework of cost and benefit is presented in the figure 3, indicating the inclusive of cost and benefit to be valuated. For the cost estimation, economic and environmental costs are considered, and the environmental cost converts health impact and noise impact. For the benefit estimation, economic, environmental and social benefits are all taken into valuation. After the valuation of each cost and benefit item, a comparison between cost and benefit is implemented in order to exanimate the economic feasibility of the project.

Figure 10 The analytical framework for the economic analysis



The total construction cost is 4,300,000 yuan which includes the pipe construction expense. The government subsidized 600,000 yuan for the initial investment. The O&M cost is 200,000 yuan every year.

Table 13 Construction cost distribution (yuan/year)

Building and equipment	1,200,000
Pipe construction	3,100,000
Total	4,300,000

Figure 11 The distribution of construction cost

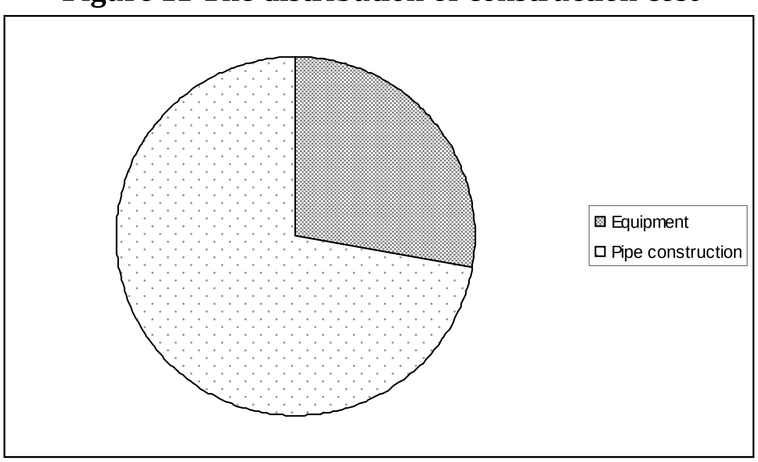
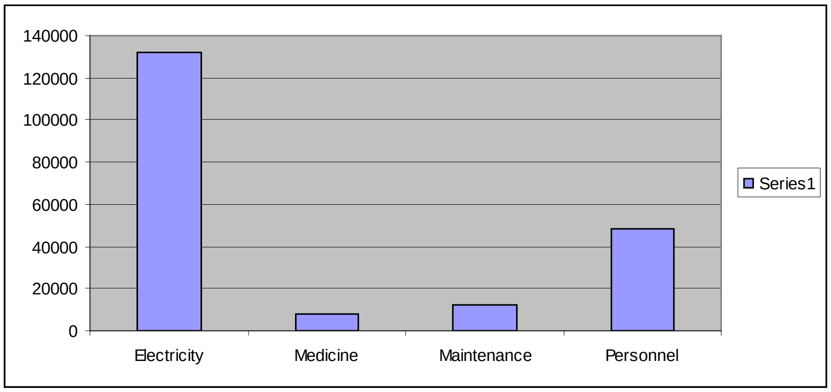


Table 14 Description of the O& M cost distribution of BNU

Electricity	500kw.h*0.722*365= 131765 yuan/year
Medicine	8000 yuan/year
Personnel	2000*2*12=48000 yuan/year
Maintenance	12235 yuan/year
Total	200,000 yuan/year

Figure 12 O&M cost distribution



The noise from the machine can not be neglected, which could become pollution to environment. Valuation of noise impact is very complicated because there are no direct market prices for noise effects. Few papers evaluate noise pollution in China and existing studies mostly make evaluations at the national and regional level. For example, Wen and Chen estimates the noise pollution of China, and Liu valuates the noise pollution in Dalian city (Liu, 1999; Wen and Chen, 2007). For simplifying the determination, we make the valuation of the noise impact through converting the value of existing literature result. Wen and Chen (2007) also take the method of converting Liu (1999)'s result to value the noise pollution of China.

Liu (1999) makes a systematic estimation of noise pollution in Dalian city through the method of Willingness To Pay. He finds that the estimated households who live in the high decibels areas, namely 66-70 decibels, would like to pay average 26 Yuan per month to eliminate the noise. So the noise pollution cost in Dalian could be regarded as around 26 Yuan/household each month which is around 9 Yuan per person every month (Liu, 1999).

We value the noise pollution cost by converting the noise pollution value of Liu (1999). The conversion can be made in terms of the difference ratio between Dalian and Beijing city. According to the Beijing statistical yearbook 2005, the average income of Beijing's resident is 1.5 times of the income of Dalian's people. Additionally the ratio of the average consumption between Beijing and Dalian is also 1.5. So we assume the cost in Beijing is 1.5 times more than the cost of Dalian city. Moreover, the noise of treatment plant is assumed to be 66-70 decibels which is similar to the noise level in the study of Liu (1999).

The unit cost of noise pollution is 9 Yuan per person each month in Dalian city. Through value conversion, the cost of noise pollution in Beijing city could be 13.5 Yuan per person each month. In the Qing project around 30 persons are affected by the noise, and in the BNU project around 10 persons are affected by the noise.

Because the plant is built closed to student restaurant which makes larger noise than the water treatment plant, the noise pollution could be neglected. The environmental cost of the health risk is considered in this paper. Similarly, the concept of DALYs is used in the estimation of health risk caused by the BNU project.

The green land area 100,000 m^2 in the campus is irrigated by reuse water. The total green area in Beijing is 107,440,000 m^2. So the percentage of green area between BNU and Beijing is 0.09%.

DALYs number
=DALY rate × population × percentage of population infected by irrigation × percentage of impact of the Qing project
$= 389 / 10^5 \times 22.5 \times 10^5 \times 8\% \times 0.09\ \%$
= 0.35 DALY/year

Valuation of health impact
= DALY cost rate × DALYs number
= 2813 * 0.7
= 1969 yuan /year

If there would be no BNU project, reuse water would be transferred to the BNU campus from the big centralized water recycling plant. Thus the avoiding costs of constructing pipes could be regarded as a social benefit of decentralized water recycling system. It is easy to find in the figure 6 that the Jiuxianqiao water recycling plant is the closest centralized plant to the BNU project. We assume that the reused water of the BNU campus could be provided by the Jiuxianqiao plant if there is no BNU project. The distance between Jiuxianqiao plant and the BNU project is at least 8 km. In the current paper, we take the least unit cost value 2000 Yuan/meter and the shortest distance value: 8 km for the estimation.

Avoiding cost of constructing pipes
= unit cost × estimated distance
= 16,000,000 Yuan

Figure 13 The location of BNU project

The Beijing normal university pays for the all operation and maintenance cost in each year. The value of the payment is 200,000 yuan/year. From the viewpoint of project manager, this amount could be regarded as the economic benefit of the project.

The principal environmental benefit of the BNU project is water resource saving. The BNU project produces around 150,000 m^3 per year. And the water resource price is 1.1 yuan/ m^3. So the environmental benefit =1.1 * 150,000 = 165,000 yuan/ year.

The BNU project could benefit to improve the social awareness of all staff and students on water saving. This could be regarded as the expense saving on education on raising social awareness. The total population of the Beijing Normal University is 35,000. According to the statistic data of the department of planning and programming, the average investment on education and research in water sector in Beijing is 2,780,000 yuan.

So the saving on educational expenditures
= total spent on waster saving education /total population * population affected by BNU project
= $2,780,000/22.5*10^5 * 35000$
= 43238 yuan/year

4.2.3 Discussion

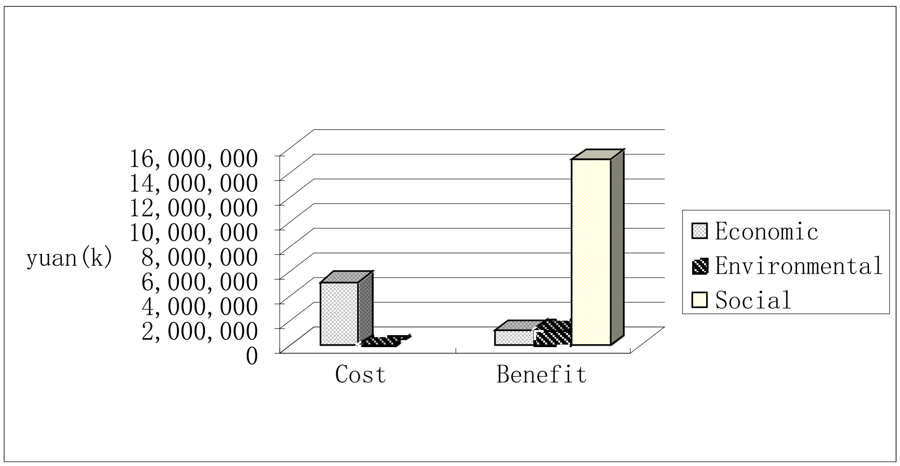
The result shows that the present value of total cost of the BNU project is around 5 million yuan, and the present value of benefit is around 17 million yuan. So the ratio of benefit and cost is larger than 1, which means the BNU project is economically feasible.

The pipe installation fee is the main expense in the initial investment, and the expense of building and equipment accounts for one fourth of total investment. About the benefit, avoiding cost of pipe construction is the major part of benefit value. The Environmental benefit is 165,000yuan every year, but the environmental cost is only 1969 yuan each year. The environmental benefit is 84 times larger than the cost. So the BNU project is environmentally friendly.

Table 15 Economic analysis result

C_{PV}= 5,150,000yuan
B_{PV}= 17,000,000yuan
$R_{B/C}$= 3.3
Feasibility? ---------------- yes

Figure 13 The comparison between cost and benefit



The BNU project produces water around 150,000 m^3 each year, and the total O&M cost is 200,000yuan each year. So the unit cost is around 1.4 yuan/m^3 which is lower that the unit cost of the Qing project.

The initial investment of the project is subsidized by the Beijing government and paid by the Beijing normal university. And the operation and maintenance cost is also paid by the Beijing normal university. Excepting the depreciation on the equipment, there is not financial loss in the BNU project. But the financial profit of the project is also zero because the yearly funding provided by the Beijing normal university is used up every year.

4.2.4 Conclusion

The result of the economic analysis reveals that the BNU project is economically feasible and the avoiding cost of pipe construction is the main benefit. The result of environmental impact implies that the BNU project is relatively environmentally friendly although it causes a negative health impact.

Because the BNU project could get subsidies from the government and the Beijing normal university, it has not any financial problem. But the project manager does not obtain any profit from the project.

4.3. The An project

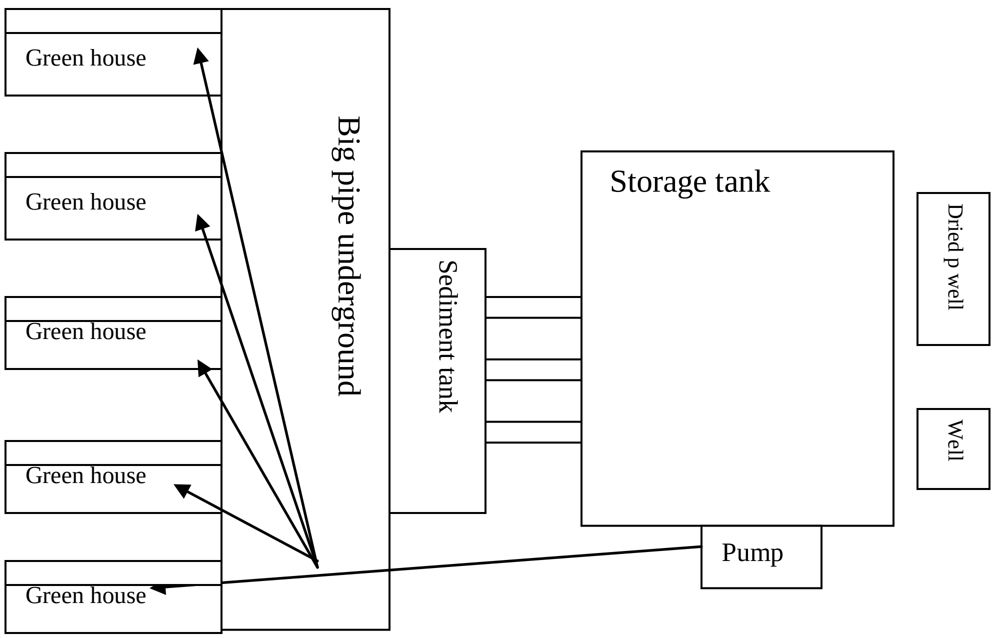
4.3.1 Project introduction

Figure 14 The location of the An project

The An (An Ge Zhuang village) project is promoting a household rainwater harvesting system in the rural areas of Beijing. The collected rainwater is used for agricultural irrigation. The An project is located in the Huairou district which belongs to the rural areas of Beijing. Like other farmers, the manager of the An project is facing the pressure of water scarcity, because he is living there.

There are three arguments that can prove that the selected project is a representative case. Firstly, the technique used in the An project is very similar to that of other projects in Beijing rural areas. The treatment process is designed by the same institute as used by others, the Institute of District Agricultural Science. The rainwater harvesting system of the An project consists of three main parts: catchments area, water storage and irrigation facilities. The catchment is based on five plastic covers for the green houses, in total a surface of 640m^2. The storage tank has a capacity of around 500 m^3, which accounts for 200 m^2. The drip irrigation method is taken up by the project. It helps to save water resources for irrigation. The whole water harvesting and reuse process is shown in the figure 13. Because there is a plastic film covering the green house, rainwater goes through the plastic film down to the ditch in front of the house. Rainwater moves from the shallow ditch to the big underground pipe and then to the sediment tank. There is a filter installed in the tank. After depositing the solids, cleaned water enters the storage tank. The water is transferred from the storage tank to the green house by pump. Both the scale of system and the treatment process of the An project is similar to that of other rainwater harvesting projects in Beijing rural area (from an interview with the manager of the An project).

Figure 15 The rainwater harvest and reuse system



(Source from interview with the owner of the An project)

Secondly, the crops planted in the An project are all the common crops in Beijing is rural areas. The main agricultural fruit plantings of Beijing are apples, pears, grapes and peaches, in which the pears and grapes production accounts for respectively 18% and 5% of total fruit production (Beijing Statistic Year book 2008). Moreover, in terms of the weight measurement, vegetables production is around 45% of all crops production in Beijing. Five crops grown in the An project includes fruits and vegetables, which are grape, pear, tomato, cabbage and mushroom. Since the rainfall in Beijing is concentrated in the period from March to September, the storage tank will be idle during other periods. It is a good idea to plant mushroom in the tank when it is not used for water storage. There are two other advantages of mushroom planting: firstly mushroom requires less water, and secondly mushrooms make high net profit.

Thirdly, the financial source are similar between the An project and other projects in Beijing's rural areas. Generally these projects are constructed and subsidized by the Institute of District Agricultural Science (source from the interview with the An project manager). The An project also obtains some subsidies from the Institute of District

Agriculture Science. The table 10 illustrates the distribution of investment between the stakeholders of the project. Moreover, the profit of crops is the main income to finance for the operation and maintenance of the system, which is also in the same situation as other projects.

Table 16 Investment funding distribution

Participants	**Proportion**
Project manager	30%
Chinese Academy of Science	35%
Institute of Huairou District Agricultural Science and other relevant bureaus	35%

(Source from interview with manager of the An project)

4.3.2 Methodology

From the point of view of the government, it is important to evaluate the contribution provided by rainwater harvesting. The evaluation includes the impact with and without subsidies, but does not look at the social and environmental impact.

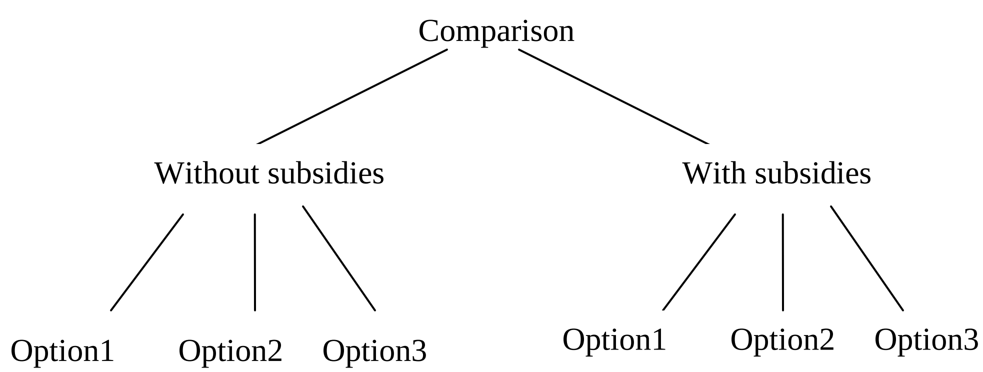


Figure 16 The framework of analysis

Figure 6 above shows the framework of analysis. As mentioned in the previous section, the An project obtains subsidies from other institutes. In the economic analysis, the initial cost should be all taken into evaluation. But from the angel of financial cash flow, the real payment of the project manager is just 30% of the initial cost. The results of cost recovery analyzed from different angels should be different. So the situations of "without subsidies" and "without subsidies" are both considered in this paper.

For the purpose of this study, three options would be evaluated and compared. As they are different models, the economic situations are also different. We try to find the economic feasibility of these three options and which option is the better option. The description of three options is shown as following.

Option 1: without the rainwater harvesting system. In this option, the irrigated water is taken from the well. The energy consumption and water consumption are much higher. But there is not any initial investment for the rainwater harvesting system. It represents the status of “no change”.

Option 2: with the rainwater harvesting system and the storage is only used for water harvesting. In this option, the large part of irrigated water is from the harvested rainwater. Due to the drip irrigation method, less water is required for irrigation. The consumption of energy will decrease as irrigated water is only transferred from the storage. Like the option 1, only four kinds of crops, grape, pear, tomato and cabbage are taken into calculation.

Option 3: with the rainwater harvesting system and the storage is used for water harvesting and mushroom planting. In this option, economic benefit and cost will increase because one more crop is involved. The water and energy consumption is decline because of the water harvesting system.

The economic indicator, Net Present Value (NPV) is used to make the comparison between three options. NPV is a common indicator in the economic analysis on rainwater harvesting system (Pandey, 1991; Tian et al., 2002; Senkondo et al., 2004; Mushtaq et al., 2007). It is assumed that the An project can function for a period of 20 years. According to the publication <Chinese Economic Evaluation Parameters on Construction> (2006), the discount rate for the study is 8% including the inflation rate of China. During the analysis period, the production cost and economic profit is assumed to be constant value. Therefore, the present value of total cost and gross benefit are, respectively,

$$GB=\sum_{t=1}^{n}\frac{B_t}{(1+i)^t}$$

$$TC=K+\sum_{t=1}^{n}\frac{C_t}{(1+i)^t}$$

Where, B_t is the economic benefit at the t year, K is the initial investment on the rainwater harvesting system including catchments, storage and irrigation facilities, C_t is the production cost at the t year, i is the discounting rate and n is the evaluation period. The following sections describe the cost and benefit item for the evaluation separately.

Therefore, the net present value is
NPV= GB-TC

If NPV>0, the option is economic feasibility, if not, the option is unfeasible. If NPV of option 1 is larger than that of option 2, that means option 1 has better cost recovery than option 2.

4.3.2.1 Initial investment cost

The initial investment cost is related to the size of the catchments and the irrigation method (Tian et al, 2003). The An project takes the drip irrigation method which could benefit to water saving and energy saving. The catchments area of the An project is five plastic covers for greenhouse planting. Since the project is located in the Beijing rural area, there is not much more space for catchments area. So it is realistic to take covers of greenhouses as the catchments. But the cost of the plastic cover and shelf is relatively higher than other cost, which accounts around 70% of the initial investment. The expense on tank building and irrigation facilities accounts for 30% of the cost.

4.3.2.2Production cost

For the agriculture production, energy cost is the main part. Normally water is pumped from the well and then transferred to irrigate. Much deeper the well is, more energy is required for pumping. If there would be no An project, around 8000 yuan per year is paid for the electricity consumption on pumping water in every year. Because of the An project, the energy cost decreases to around 1000 yuan each year. So both the drip irrigation method and rainwater storage could benefit to save the energy consumption efficiently.

Other agriculture production cost concern the fertilizer cost, cost of planting and crop transferring cost. Compared to the energy cost, the remaining production cost is only three fourth of the energy cost.

In this study the maintenance cost is included in the production cost. But there is no detailed list of maintenance expenditure. The maintenance cost should be the cost of replacing parts of facilities.

4.3.2.3Economic benefit

Obviously the crop yield is the main benefit of the An project. The grapes, pears, tomatoes and cabbages are normal planted in March and harvested in September, so they only contribute to the profit once each year. The rainy period of Beijing is from March to September, which is also the planting period of these four crops.

To increase the economic benefits, mushroom production is taken up in the An project. Mushrooms are planted in the storage and can be harvested several times per year. Its profit is higher than that of other crops.

4.3.2.4 Benefit of water resource saving

Without the An project, irrigated water would be pumped from the well, implying the use of underground water. Since the An project is constructed, the main part of irrigated water is the rainwater. Moreover, the drip irrigation method saves more water. Saving water could be regarded as a benefit of the An project. According to the regulation in Beijing, the rate of water resource is 1.1 yuan per cubic meter.

4.3.2.5 Data description

All cost and benefit data for the evaluation are collected through the interview with the manager of the An project. Since it is a project with private involvement, the relevant data is recorded systematically. The table below indicates the cost and benefit of the An project in year 2008.

Table 17 The list of cost and benefit value

Item	Value
Initial investment	350000 yuan
Production cost (without mushroom)	7280 yuan/year
Production cost (with mushroom)	44780 yuan/year
Economic benefit (without mushroom)	42000 yuan/year
Economic benefit (with mushroom)	117000 yuan/year
Benefit of water resource saving	440 yuan/year

4.3.3 Discussion

Figure 3 below shows the comparison of the NPV values for the three options during the evaluation period. Both option 2 and option 3 represents the situation of “change”, and the option 1 represents the situation of “no change”. Because there is no initial investment in the Option 1, the NPV of senario1 is always larger than zero. The duration of time when the net benefit compensates for the total investment is the capital recovery period. The capital recovery period of the option 3 is 6 years, but the capital recovery year of the option 2 is relatively longer, 19 years. Compared with “no change”, obviously the option 2 is not a good option. The NPV value of the option 2 is always negative during the estimated period. It means that it is not economically feasible to build the rainwater harvesting system if there is not subsidy or other incomes to recovery the cost. The yields of four kinds of crops are too small to cover the cost of the system.

However, the situation could become better if using the storage for mushroom planting. In the option 3, it only takes 6 years to recovery the cost. At the 14^{th} year, the NPV of the option 3 is almost same to the option 1. After then, the NPV of the option 3 has higher value than that of the option 1. Mushroom planting helps to increase the total profit so that the option 3 is economic feasible. But it will take 14 years to make the net benefit to reach the level of “no change” situation. The period of 14 years seems to be too long time. The peasants may prefer to keep the “no change” situation rather than engaging in this project.

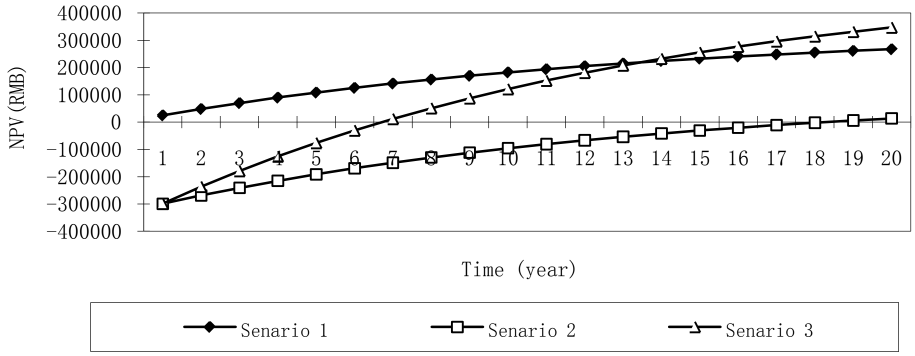
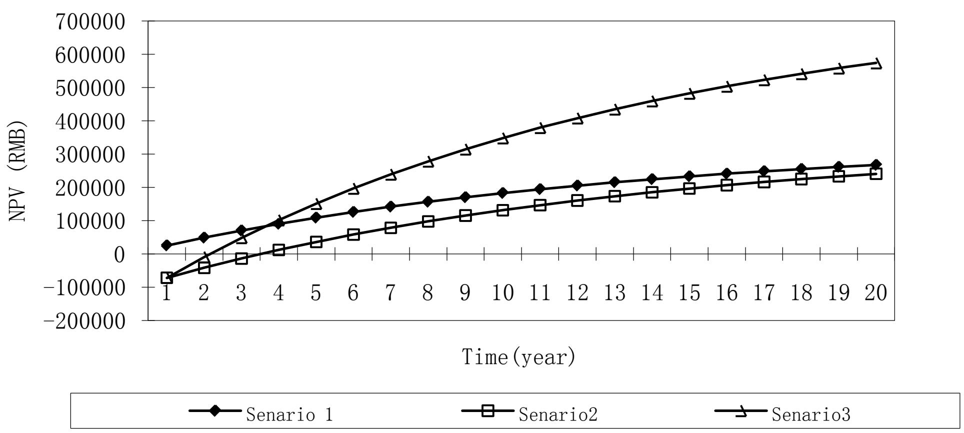


Figure 18 Comparison of three options without subsidies

Generally the project of rainwater harvesting could be subsidized by the government and related institutes. The An project obtained a total of 70% subsidies and the project manager just pays 30% of the initial investment, which is around 105,000 yuan. If we consider the subsidies as a benefit to the project manager, the initial investment cost will become 105,000 yuan. Then the evaluation result will be changed as shown in the figure 8 below. Apparently the option 3 is still the best option as it just takes two years to recover the initial cost. After 4 years, its NVP value starts to take over the option 1 and grows faster. If there is not mushroom planting, the cost recovery period could become four years. Although the option 2 becomes to be economic feasible under the condition of financial subsidies, its NPV line is still below than the option1. The difference between two options is around ten thousands yuan which is a large amount to the people living in Beijing rural area. So the option 2 is not the preference option even though it is economically feasible.

Figure 19 Comparison of three options with subsidies



The discussion above implies the availability of subsidies will affect the results of economic analysis significantly. If there is no subsidy to finance the project, the rainwater harvesting system could become a big burden for the project manager. Other sources of finance such as mushroom planting may solve the problem, but it not a preferred option. After obtaining subsidies, the project becomes economically feasible even though there is no mushroom planting. Moreover, it shortens the cost recovery period. We find that the option 3 with subsidies is the only preferred option. Mushroom planting promotes the profit making and effectively finances the rainwater harvesting system.

4.3.4 Conclusion

The paper makes a comparison between three options under two different conditions: with and without subsidies. It takes net present value as the measurement for the comparison. The results reflect how difficult it is to carry out the project in the long term if there are no subsidies. The situation of "change" is not better than the situation of "no change". However if there are subsidies, the project becomes economically feasible and the cost recovery period will become shorter. Taking subsidies and meanwhile using the storage tank for mushroom planting makes the situation of "change" better than "no change". In this way the farmer can make sure the rainwater harvesting system will be financially sustainable in long term.

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