018530 - SWITCH

Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

D 6.4 1 A conceptual framework for evaluating the financial side of the relevant infrastructure in demo projects and selected cities

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SWITCH Deliverable Briefing Note

SWITCH Document
D6.4.1: A conceptual framework for evaluating the financial side of the relevant infrastructure in the demo projects and selected cities.

Audience
This document was prepared for an audience both inside and outside the SWITCH consortium.
For consortium members it gives the intended SWITCH approach to economic evaluations of urban water management projects. Consortium members are invited to follow this approach when doing their research, and to provide feedback.
The external audience consists of urban water managers that would like to rethink their approach to urban water management, but want the financial, economic, environmental and social arguments for alternative options.

Purpose
The purpose of the document is to explore the financial and economic implications of alternative approaches to sustainable urban water management through the method of cost benefit analysis. It aims to find out whether the proposed system is an economically viable alternative 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. It was the proposal for PhD research under the Switch project, which is now ready and available as a deliverable.

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
Is Cost benefit the most appropriate method for evaluating alternative options in integrated urban water management?

Recommendations
The choice of cost and benefits is crucial and depends on the available information, but also on the willingness to collect new data and to try different approaches to getting indicators for these effects.

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A conceptual framework for evaluating the financial side of the relevant infrastructure in demo projects and selected cities

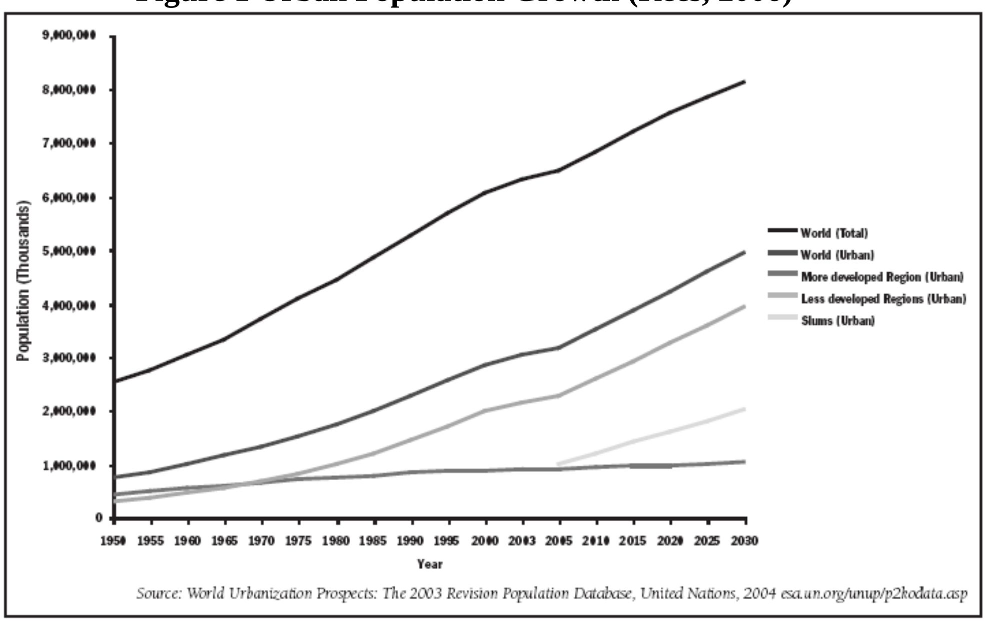
Xiao Liang and Meine Pieter van Dijk, April 2009

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, 2007). 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.

1.2Different 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).

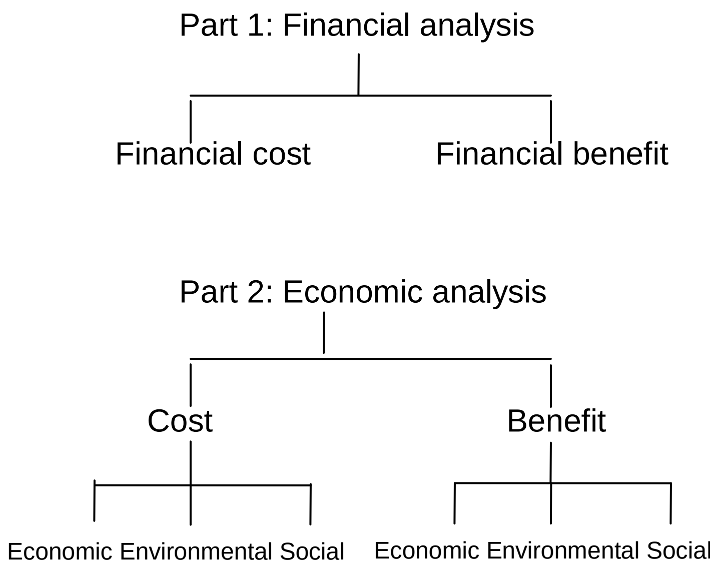
At this point the question should be raised whether the decentralized system is indeed the optimal alternative to a centralized system. Is the decentralized system economic competitive with the centralized system? The research of theme 6.4 will investigate and critically discuss this issue.

2. Research approaches

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.

Figure 2 Two parts in the analysis



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

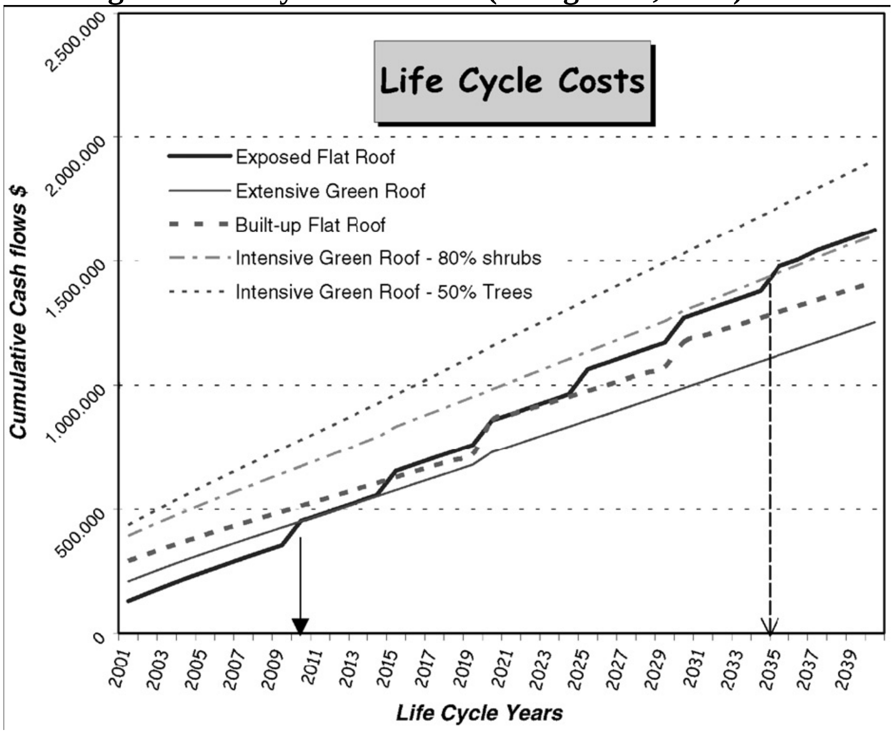
Source: Van Dijk (2006)

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.

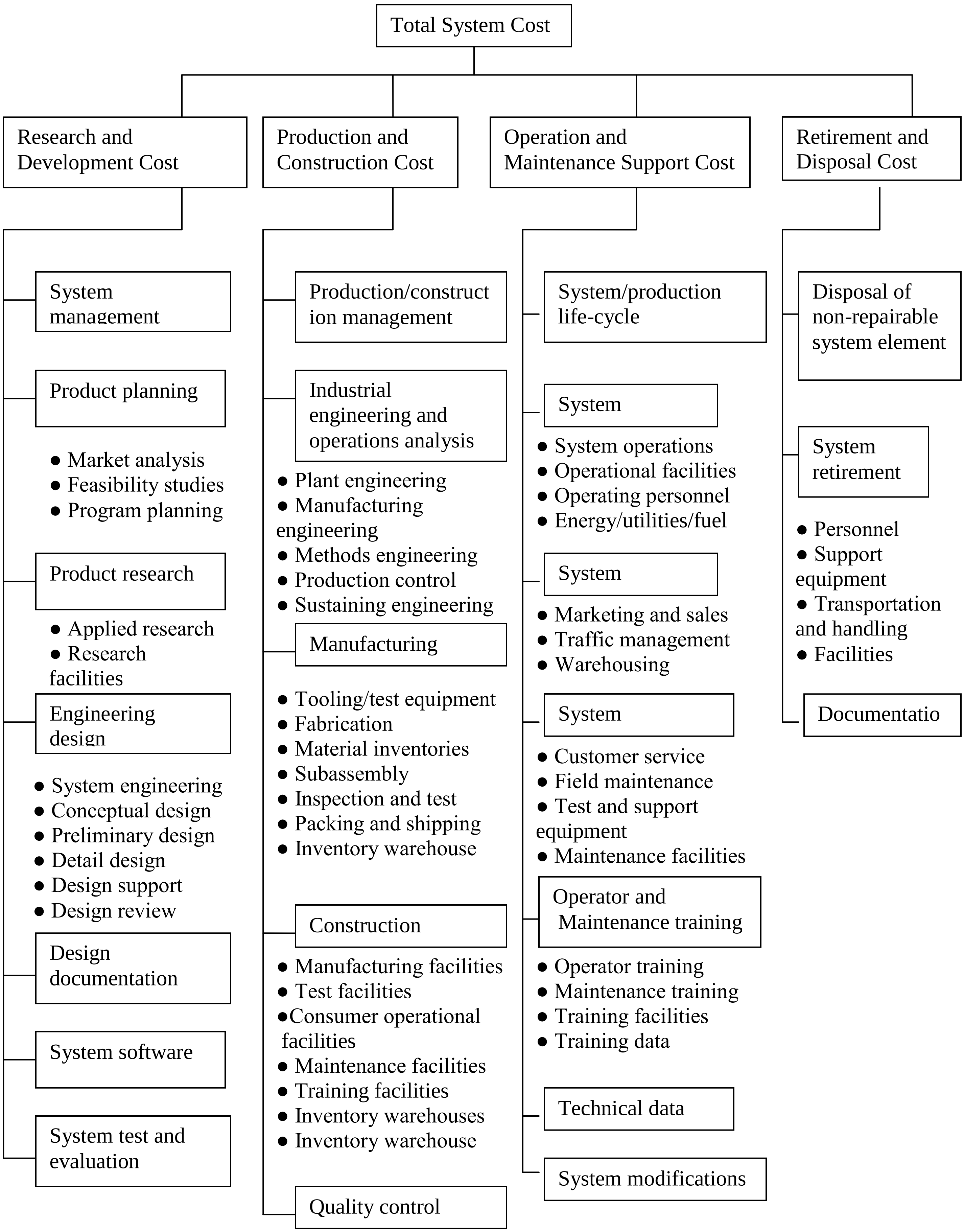


Figure 4 A general cost breakdown structure (Fabrycky and Blanchard, 1991)

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).

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.

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.

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).

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)

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

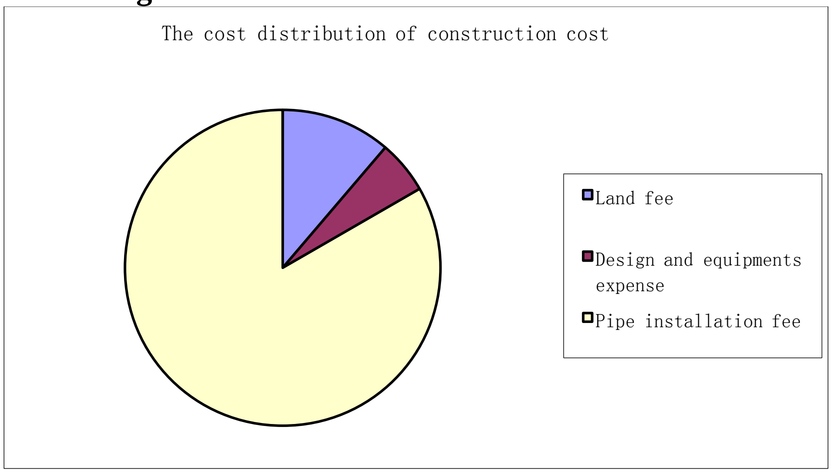
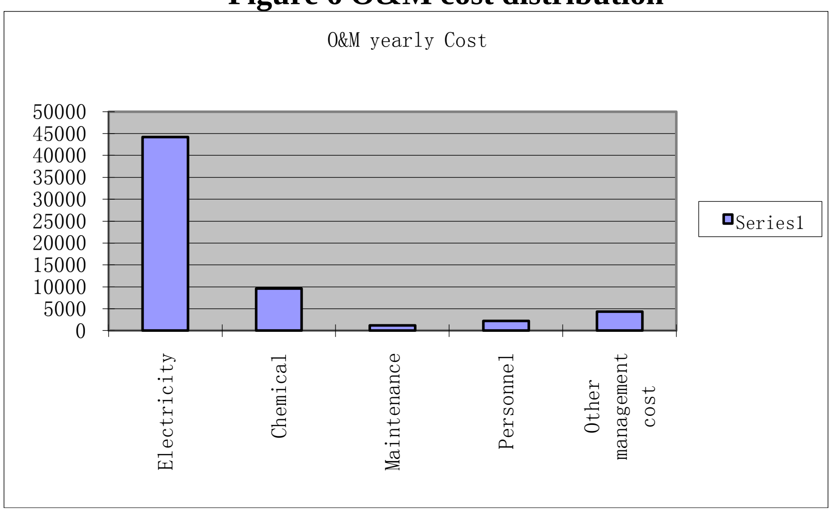


Figure 6 O&M cost distribution



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, 2007) 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 $442 \times 10^{-5} \times 0.88 = 389*10^{-5}$ 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, 2007), 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, 2007).

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

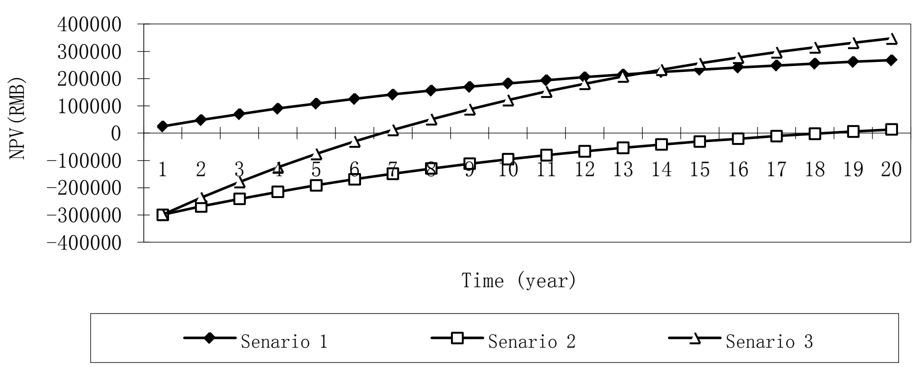
2.4 Measures for comparative analysis

2.4.1 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.

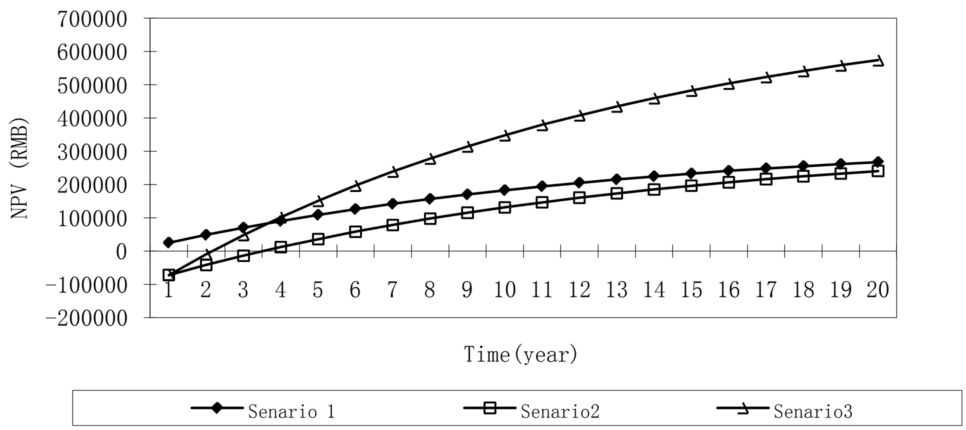
However, the situation could become better if using the storage for mushroom planting. In the option 3, it only takes 6 years to recovery the cost. At the 14th year, the NPV of the option 3 is almost same to the option 1. After then, the NPV of the option 3 has higher value than that of the option 1. 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.

$$\mathrm{C}=\mathrm{C}_{\mathrm{O}}+C_S+C_E$$

$$\mathrm{B}=\mathrm{B}_{\mathrm{O}}+B_S+B_E$$

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

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 $\lambda >$ social interest rate, then the alternative system is economic feasibility,
if $\lambda <$ 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.

$$\mathrm{C}=\mathrm{C}_{\mathrm{O}}+C_E$$

$$\mathrm{B}=\mathrm{B}_{\mathrm{O}}+B_S+B_E$$

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

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 -- Beijing Qing project, BNU project and An project

This chapter provides only a brief introduction, analysis in the other deliverable a more detailed analysis of the projects will be provided.

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.

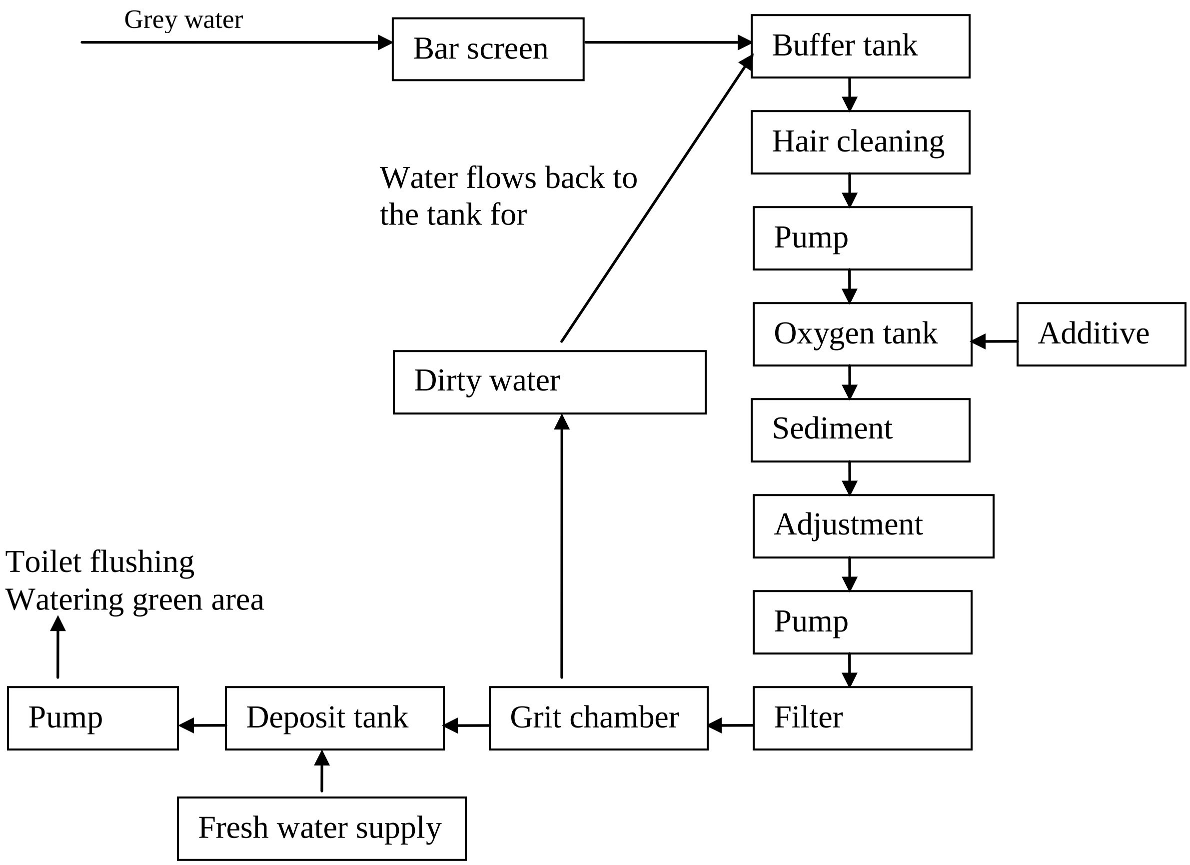
The present case studies try to evaluate the decentralized water recycling system through an economic feasibility analysis and a financial appraisal study. In the economic analysis, full cost and benefits are evaluated separately. For the evaluation of the environmental cost, the concept of DALYs is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

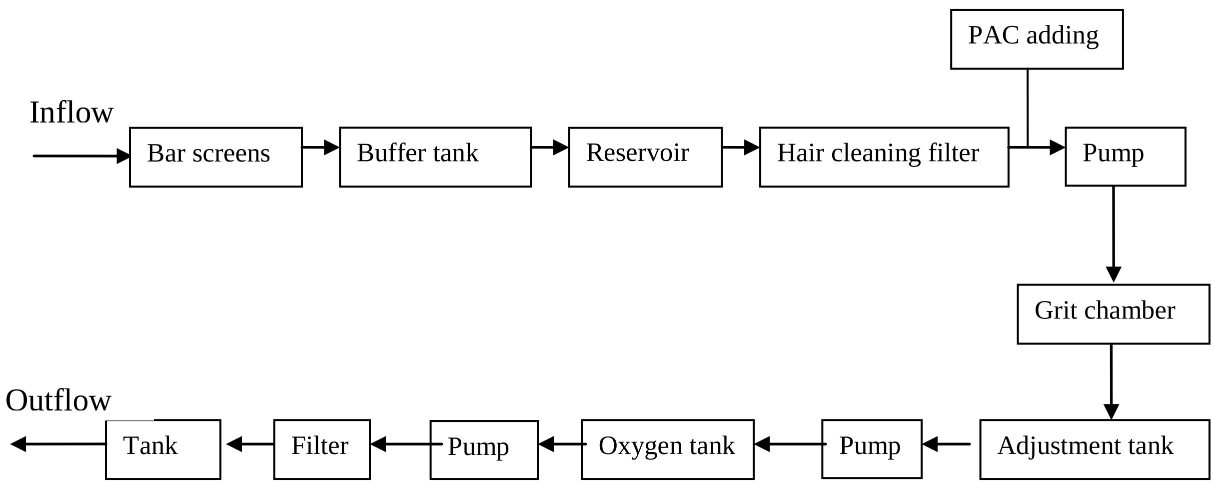


Source from interview with the manager of Qing project)

3.2 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.

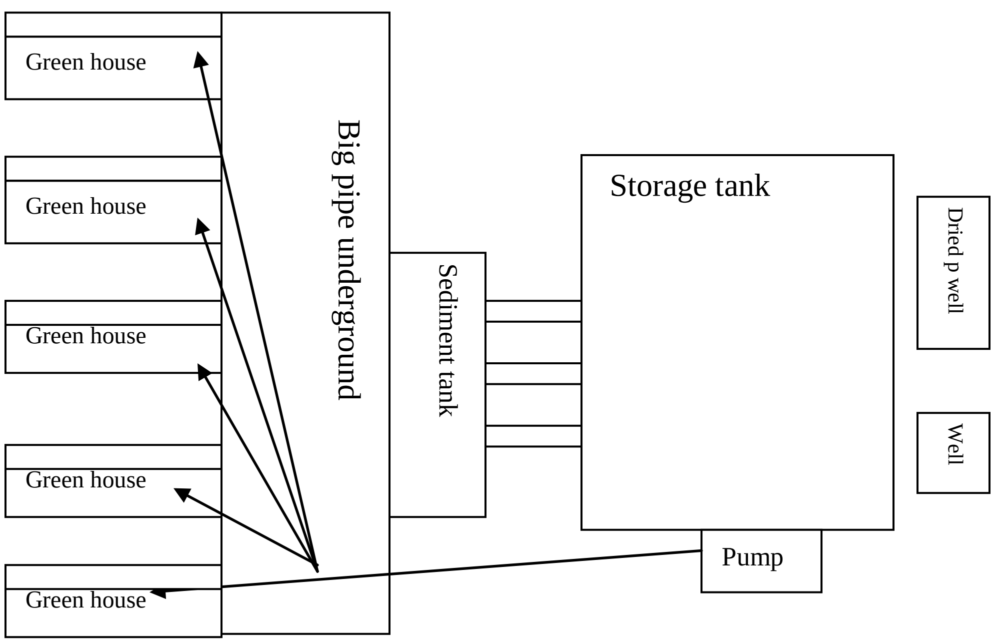
The BNU project produces water around 150,000 m^3 each year. The initial investment of the project is subsidized by the Beijing government and paid by the Beijing normal university. And the operation and maintenance cost is also paid by the Beijing normal university. Excepting the depreciation on the 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 Conclusions

The purpose of the document was to explore the financial and economic implications of alternative approaches to sustainable urban water management through the method of cost benefit analysis. It aimed to find out whether the proposed system is an economically viable alternative to the existing system by making a comparison between the alternative approaches. The results of the research should help decision makers to select the more suitable solutions.

References

Anderson, J.M., 1996. Current water recycling initiatives in australia: Scenarios for the 21st century. *Water Science and Technology*, **33**, 37-43.

Angelakis, A.N., Bontoux, L. and Lazarova, V., 2003. Challenges and prospective for water recycling and reuse in eu countries. *Water Science and Technology*, **3**, 59-68.

Aramaki, T., Galal, M. and Hanaki, K., 2006. Estimation of reduced and increasing health risks by installation of urban wastewater systems. *Water Science and Technology*, **53**, 247-252.

Asano, T., 2005. Urban water recycling. *Water Science and Technology*, **51**, 83-89.

Ashley, R.M., Souter, N., Butler, D., Davies, J., Dunkerley, J. and Hendry, S., 1999. Assessment of the sustainability of alternatives for the disposal of domestic sanitary waste. *Water Science and Technology*, **39**, 251--258.

Bao, C. and Fang, C., 2007. Water resource constraint force on urbanization in water deficient regions: A case study of the hexi corridor, arid area of nw china. *Ecological Economics*, **62**, 508 -517.

Birol, E., Karousakis, K. and Koundouri, P., 2005. Using a choice experiment to estimate non-use values: The case of cheimaditida wetland. *Water Science and Technology: Water Supply*, **5**, 125-185.

Boardman, G. and Vinning, W. (1996). Cost benefit analysis concepts and practice, Prentice Hall: Upper Saddle River New Jersey

Braden, J.B. and Van Ierland, E.C., 1999. Balancing: The economic approach to sustainable water management. *Water Science and Technology*, **39**, 17-23.

Campbell, H. and Brown, R., 2005. A multiple account framework for cost benefit analysis. *Evaluation and Program Planning*, **28**, 23-32.

Christova-Boal, D., Eden, R.E. and McFarlane, S., 1996. An investigation into greywater reuse for urban residential properties. *Desalination*, **106**, 391-397.

DPP (2001). The water planning in beijing, Chinese Department of Planning and Program.

Durairaj, S.K., Ong, S.K., Nee, A.Y. and Tan, R.B., 2002. Evaluation of life cycle cost analysis methodologies. *Corporate Environmental Strategy*, **9**.

Fabrycky, W.J. and Blanchard, B.S. (1991). Life cycle cost and economic analysis. New Jersey, Prentice Hall.

Hauger, M.B., Rauch, W., Linde, J.J. and Mikkelsen, P.S., 2002. Cost benefit risk- a concept for management of integrated urban wastewater systems? . *Water Science and Technology*, **45**, 185-193.

Jenerette, G.D. and Larsen, L., 2006. A global perspective on changing sustainable urban water supplies. *Global and Planetary Change*, **50**, 202-211.

Larsen, T.A. and Gujer, W., 1997. The concept of sustainable urban water management. *Water Science and Technology*, **35**, 3-10.

Lazarova, V., Levine, B., Sack, J., Cirelli, G., Jeffrey, P., Muntau, H., Salgot, M. and Brissaud, F., 2001. Role of water reuse for enhancing integrated water management in europe and mediterranean countrieswater science & technology. *Water Science and Technology*, **43**, 25-33.

Lens, P., Zeeman, G. and Lettinga, G. (2001). Decentralized sanitation and reuse: Concept, system and implementation. Cornwall, UK, IWA Publishing.
Liu, F.X., 1999. The study on the monetary cost of noise pollution in dalian city *Liaoning Urban Environmental Technology* **19**, 27-29.
Mills, R.A. and Asano, T., 1996. A petrospective assessment of water reclamation projects. *Water Science and Technology*, **33**, 59-70.
Mishan, E.J. (1988). Cost-benefit analysis. London, Unwin Hyman.
Murray, C. and Lopez, A.D., 1997. Global mortality, disability, and the contribution of risk factors: Global burden of disease study. *The Lancet*, **349**, 1436-1442.
OECD (2007). Unsafe water, sanitation and hygine: Associated health impact and the costs and benefits of policy interventions at the global level Working Party on National Environmental Policies E. p. committee.
Ottoson, J. and Stenström, T.A., 2003. Faecal contamination of greywater and associated microbial risks. *Water Research*, **37**, 645-655.
Parkinson, J. and Tayler, K., 2003. Decentralized wastewater management in peri-urban areas in low-income countries. *Environment and Urbanization*, **15**, 75-90.
People's Daily, 2000. City residents aware of water scarcity. *http://english.people.com.cn/english/200006/30/eng20000630_44367.html*.
Postel, S.L., Daily, G.C. and Ehrlich, P.R., 1996. Human appropriation of renewable fresh water *Science* **271**, 785-788.
Psychoudakis, A., Ragkos, A. and Seferlis, M., 2005. An assessment of wetland management scenarios: The case of zazari-cheimaditida(greece). *Water Science and Technology: Water Supply*, **5**, 115-124.
Rees, J.A. (2006). Urban water and sanitation services: An iwrm approach. Tec background papers. G. W. Partnership.
Rogers, P., Silva, R. and Bhatia, R., 2002. Water is an economic good: How to use prices to promote equity, efficiency, and sustainability. *Water Policy*, **4**, 1-17.
Song, Q., Zuo, Q. and Yang, F., 2004. Water problems brought out by citifying construction and measures. *Journal of Water Resource and Water Engineering (in Chinese)*, **15**, 56-58.
Tsagarakis, K.P., 2005. New directions in water economics, finance and statistics. *Water Science and Technology: Water Supply*, **5**, 1-15.
UN (2004). World population prospects: The 2004 revision. New York.
Wen, Z. and Chen, J., 2007. A cost-benefit analysis for the economic growth in china *Ecological Economics*, **02885**, 11.
WHO, 2004. Global burden of disease report **www.who.org**.
WHO, 2005. Review research on the literature of diarrhea disease in china. *National Center for Rural Water Supply Technical Guidance,China CDC*.
WHO, 2007. Estimating the costs and health benefits of water and sanitation improvements at global level. *Journal of Water and Health*, **05**, 467.
Wong, N.H., Tay, S.F., Wong, R., Ong, C.L. and Sia, A., 2003. Life cycle cost analysis of rooftop gardens in singapore. *Building and Environment*, **38**, 499 – 509.
WorldBank, 2007. Analysis on china northern cities' water management. *http://www.worldbank.org.cn/Chinese/content/ncwqms_cn.pdf*.

Worldbank (2007). Cost of pollution in china: Economic estimates of physical damages, www.worldbank.org/eapenvironment

Zhang, X. (2002). Valuing mortality risk reductions using the contingent valuation methods: Evidence from a survey of beijing residents in 1999. Second World Congress of Environmental Economist. Beijing.