3rd SWITCH Scientific Meeting
Belo Horizonte, Brazil
30 Nov – 4 Dec 2008

Economic and Financial Analysis of Decentralized Water Recycling Systems in Beijing

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Abstract
This paper tries to explore the economic and financial implications of the decentralized water recycling systems in Beijing. Two essential stakeholders, government and project manager, are involved in the management of the water recycling systems. From the perspective of government, economic feasibility means the project has the positive impact on society and the environment. But from the viewpoint of project manager, whether the project is profitable or not is more important. So we will do economic feasibility analysis and financial appraisal to substantiate the two different approaches. The result of economic analysis shows that the decentralized system is economic feasibility and it proves the decentralized system is an environmental friendly system. However, the result of financial appraisal result reflects that the system has serious financial performance problem.

Keywords: economic analysis, financial appraisal, water recycling

1. Introduction

To solve the water scarcity problem in Beijing, the municipal government issued a series of regulations on building wastewater recycling systems. In 1987, the first regulation, called <Temporary water reclamation and reuse regulation> was enacted. It states that all institutes, schools and hotels of which a construction area larger than 30,000 m^2 must have their own water recycling system. In 2000, a more complete regulation on constructing water recycling system in Beijing was generated. Following that, the standards for recycling water quality and the standards for recycling systems were fixed. This includes wastewater source standards, water quality standards, and wastewater reclamation technique standards. Because of these policies, around 1000 decentralized wastewater recycling systems have been constructed and are operational in Beijing. The number of decentralized systems in Beijing is still increasing and will continue to rise in future. The Beijing municipal government expects that the reused water production of all systems could reach 1million m^3 in the year of 2008 and will reach 1 billion m^3 in 2010 (Beijing Daily, 2007). Except for industrial WWT systems, many decentralized waste water recycling systems obtain subsidies from the Beijing municipal government.

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However the total actual reuse water production in Beijing is less than what was expected. One reason is that the production of certain centralized and some decentralized water recycling systems are less than their design capacities(Zhang et al., 2007). Another important reason can be that some of decentralized systems stopped their operations because of financial problems. These problems could be high operational cost, limited financial resources and poor management. Financial losses affect the performance of the decentralized systems in Beijing negatively so that the actual production of the decentralized system is decreasing.

Research should pay attention to the financial problems of the decentralized waste water recycling systems. But the literature mainly discusses the benefits of decentralized system for water resource management in Beijing. Compared to large centralized systems, decentralized systems are regarded to be less resource intensive and more ecologically friendly (Lens et al., 2001). Few papers survey the financial issues of the decentralized water recycling systems in Beijing.

The current research tries to explore the economic and financial implications of the decentralized water recycling systems. Through an intensive study of some water recycling systems in Beijing, the economic and financial problems could be analyzed. Two essential stakeholders, government and project manager, are involved in the management of the decentralized water recycling systems. The viewpoints of these stakeholders on water recycling may be different. From the perspective of government, economic feasibility means the project has the positive impact on society and the environment. Hence the economic, social and environmental impacts should be considered. But from the view point of project manager, financial feasibility is more important, which means that the construction and O&M costs should be recovered by revenue. Whether the project is profitable or not is very important for the project manager. We will do an economic feasibility analysis and a financial appraisal to substantiate the two different approaches.

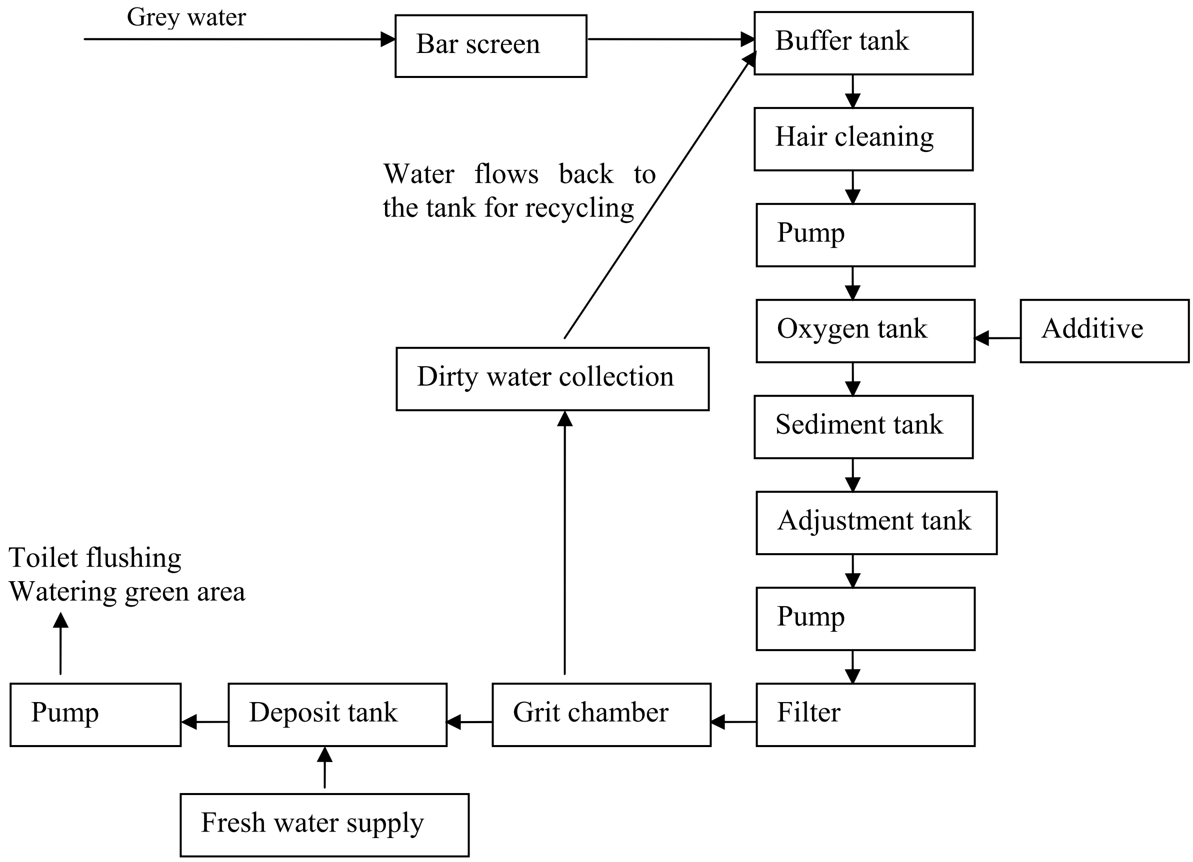
2. Description of the investigated project

The Qing project is located in a residential area in the Beijing city centre, built in 2003. Like other decentralized systems, the Qing project is constructed due to the above-mentioned policy of Beijing municipal government. 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 1, 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.

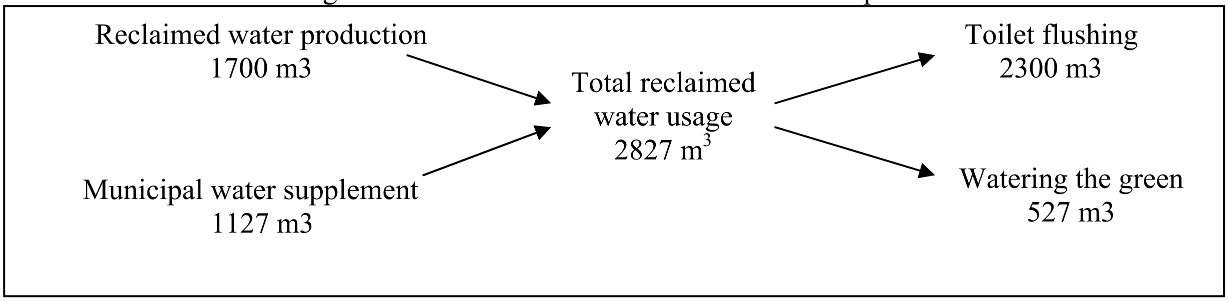
The reclaimed water is reused to flush toilet and to water the green area. Actually the produced reuse water can not satisfy the water requirement, so part of the “reused water” is supplemented by municipal fresh water. This is illustrated in figure 2. Almost half of the reused water is supplemented 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.

Figure 1 Wastewater reclamation flow chart



Source: from interview with the manager of Qing project

Figure 2 Production and use of reclaimed water per month

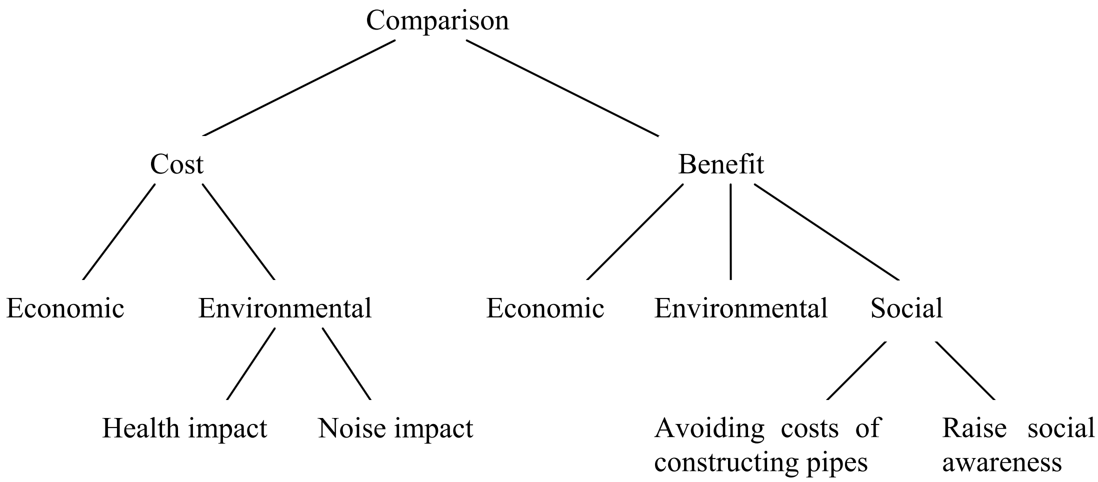


Source: from interview with the manager of Qing project

3. 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



3.1 Economic cost

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 1 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.

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.

Figure 4 The distribution of construction cost

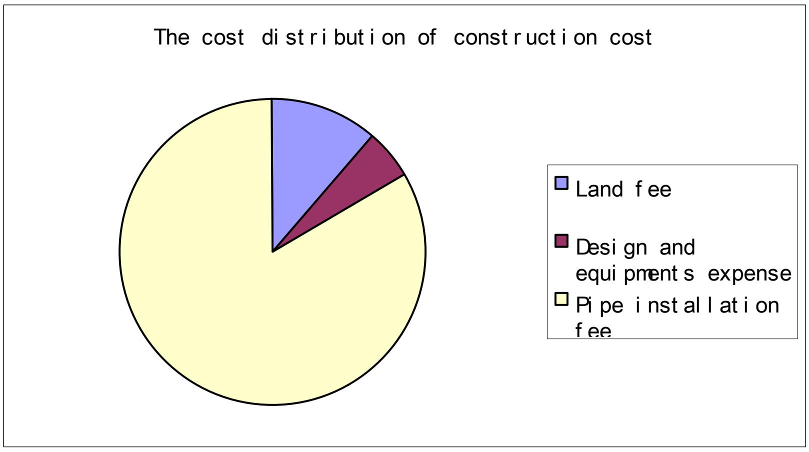
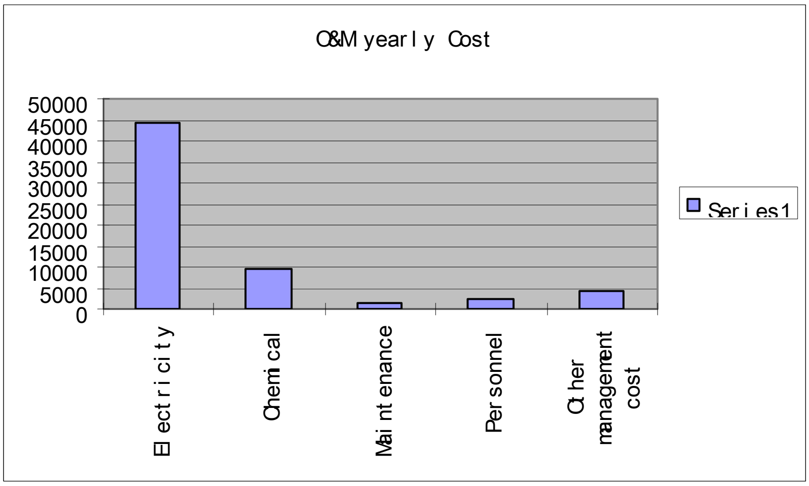


Figure 5 O&M cost distribution



3.2 Environmental Cost

3.2.1 Health impact

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, 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 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 3 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, 2007), 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 4 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
= $(14+0.22) \times 10^9 / 5055{,}000$
= 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

3.2.2 Noise impact

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 5 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

3.3 Economic 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 around 20,148 m^3.

Economic benefit
= reused water price × reused water amount
=20400 Yuan/ year

3.4 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

= unit value × reused water amount

= 22440 Yuan / year

3.5 Social benefits

3.5.1 Avoiding costs of constructing pipes

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.

Figure 6 The location of Beijing centralized water reclamation plants

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

3.5.2 Project raises social awareness concerning a new water culture

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

3.6 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.

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

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

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

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

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

4. Financial appraisal

From the view point of project manager, profitability is the basis of a financially sound project. The profit of operation should be at least cover the costs of the operation of the project. Otherwise, there is not incentive for project manager to operate the system so as to influence the sustainable performance of a decentralized system. Financial appraisal could not be ignored in the evaluation.

We use the method of life cycle cost analysis for the financial appraisal. The life cycle cost analysis method is used for the financial appraisal, because it is a systematic analytical process for evaluating various designs or alternative courses of actions (Durairaj et al., 2002). In terms of the model of the Fabrychy and Blanchard (Fabrycky and Blanchard, 1991), a cost breakdown structure should be made to specify 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. Accordingly the cost breakdown of the Qing project is shown in the table 6.

Table 6 Cost breakdown structure on Qing project

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

It is shown in table 6 that total life cycle cost is related to construction cost, O&M cost and the residual value. Construction cost and O&M cost have been discussed in the previous section. About the residential value, three parts are considered: machines, pipes and buildings. The residual value is the value left after the depreciation of the materials. A linear depreciation method is used, namely $value_{residual} = value_{original} \times \frac{year_{used}}{year_{life}}$ in which the depreciated rate is usage period divided by the total life time. We assume the life time of the Qing project is 10 years in total. The machine could be expected to be used for 15 years (sourced from the interview with the machine producer), but normal usage time is 10 years. The pipe is assumed to be used for 15 years without any replacement or repairs. According to <Chinese Economic Evaluation Parameters on Construction>, generally the construction building in water sector could be used for 50 years.

Similar to the economic analysis, the present value of cost and revenue would be calculated and then the comparison is made between cost and revenue value. The rate of the reclaimed water charged from the consumers is the main revenue of the water recycling system, which is 43000 Yuan per year. The ratio of income and cost is the standard to testify the financial feasibility of the Qing project. If it is $R_{I/C} > 1$, the project is financially feasible. Otherwise, the project is not financially feasible. The equations of the financial analysis are:

$$C_{total} = C_{construction} + C_{O\&M} - C_{residual}$$

$$I = total\ revenue$$

$$C_{PV} = \sum_{t=0}^{t=n} \frac{C_t}{(1+r)^t} = 2{,}776{,}000 \text{ Yuan}$$

$$I_{PV} = \sum_{t=0}^{t=n} \frac{I_t}{(1+r)^t} = 101{,}000 \text{ Yuan}$$

$$R_{I/C} = \frac{I_{PV}}{C_{PV}} = 0.04$$

5. 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

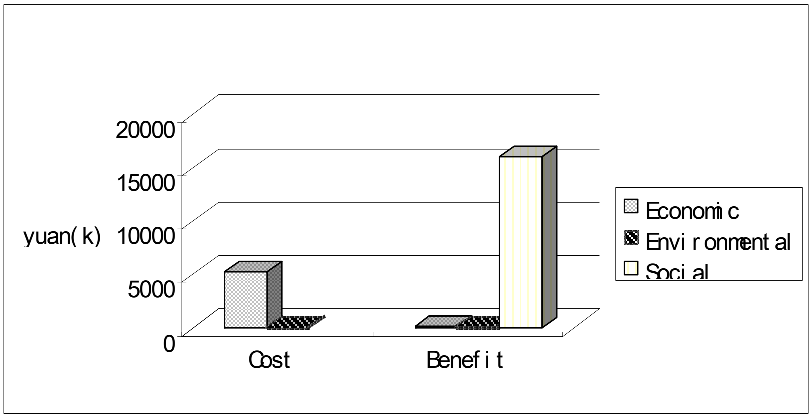


Table 7 Final economic and financial analysis result

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 8 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.

6. 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) .

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