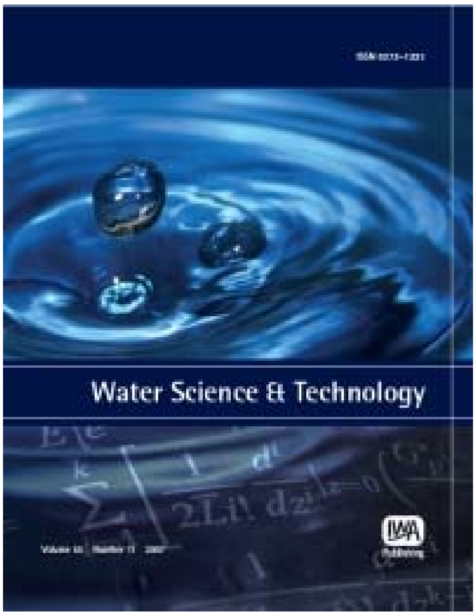
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Financial and economic feasibility of decentralized wastewater reuse systems in Beijing

Xiao Liang and Meine Pieter van Dijk

ABSTRACT

Many decentralized wastewater reuse systems have been constructed in Beijing. However their performance is not as good as expected. The total amount of reclaimed water used in Beijing is much less than the designed capacity. In order to understand the reasons causing such poor performance, an integrated financial and economic feasibility analysis for the decentralized wastewater reuse systems in Beijing is carried out in this paper. The monetary values of all the major economic, environmental and social effects are quantified. The financial analysis is made from the viewpoint of the project manager, while the economic analysis is done from the angle of government. The results show that the decentralized wastewater reuse systems in Beijing are economically but not financially feasible. It is found that the low rate actually charged for reclaimed water is an important reason for the system not being financially feasible. The decentralized wastewater reuse systems in Beijing may not continue to operate if the financial problems are not solved.

Key words | decentralized wastewater reuse systems, economic analysis, financial analysis, reclaimed water

Xiao Liang (corresponding author)
Meine Pieter van Dijk
Department of Management and Institutions,
UNESCO-IHE Institute for Water Education,
Westvest 7,
2611 AX, Delft,
The Netherlands
E-mail: *x.liang@unesco-ihe.org*;
m.vandijk@unesco-ihe.org

INTRODUCTION

To solve the water scarcity problem in Beijing, the municipal government of Beijing has issued a series of regulations on building wastewater reuse systems. The first regulation, called "Temporary water reclamation and reuse regulation" was enacted in 1987. It states that all institutes, schools and hotels in Beijing with a construction area larger than 30,000 m^2 must have their own wastewater reuse systems. In 2000, a more comprehensive regulation on constructing wastewater reuse systems in Beijing was introduced. Standards for wastewater reuse were fixed, which include wastewater source standards, wastewater reclamation technique standards and reclaimed water quality standards. Since the implementation of these policies, around 1,000 decentralized wastewater reuse systems have been constructed in Beijing and are operational. The number of decentralized systems in Beijing is still increasing and will continue to rise in the future.

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The performance of these decentralized wastewater reuse systems is not as good as expected. The average utilization of wastewater reuse systems is less than 50%, and in some extreme cases the utilization ratio would be less than 10% (Zhang *et al.* 2007). Accordingly the operations of some small wastewater reuse systems have been suspended.

The existing technology for wastewater reuse has developed to the point where it is technically feasible to produce water of any quality (Asano 2005). Small size wastewater reuse systems are now capable of producing reclaimed water in a reliable way. However, to become competitive, a system must achieve both physical and economic efficiency. Hence more research should be done on determining whether wastewater reuse systems are financially and economically efficient.

The studies of financial and economic feasibility have been carried out by several researchers. These papers either mainly try to prove that the technologies are economically feasible and worthwhile to be developed further, or they seek to find the relation between the scale of treatment plant and the cost of running it (Tsagarakis *et al.* 2000; Nurizzo *et al.* 2001; Yamagata *et al.* 2003; Friedler & Hadari 2006; Maurer 2009). It is rare that both financial feasibility and economic feasibility are evaluated in one paper. Moreover, generally, only internal costs such as initial investments and operation and maintenance costs are taken into consideration. Few papers try to quantify the environmental and social effects (Genius *et al.* 2005; Tziakis *et al.* 2008).

The current paper aims to make an integrated financial and economic feasibility analysis of decentralized wastewater reuse systems in Beijing. The economic analysis determines the contribution of a proposed project to the development of the total economy, while the financial analysis is to judge how much the individual participant could live with the project (Gittinger 1982). The present research takes into account the fact that different decision makers with different points of view may have different judgments on the same event. One effect is regarded as beneficial by one decision maker, but it can imply higher costs to the other one. For example, taxes are treated as costs from a private perspective while in the public case they are not treated as costs. Project managers and government, as the two important stakeholders of wastewater reuse systems, could have different viewpoints. Thus the financial analysis takes the viewpoint of individual participants, namely the project manager in this case while the economic analysis takes that of society, both of which are complementary in the study.

EVALUATION FRAMEWORK

As illustrated in Figure 1, the financial analysis encompasses an evaluation of the financial cost and benefits, assessing the financial performance of the investments. In the economic analysis, the major economic, environmental and social effects are selected and quantified. The monetary value of each effect is obtained principally through an indirect valuation method. Transfer payments such as subsidies are not considered in the economic analysis because they do not consume or create any new value for the society (Dahmen 2000). Cost benefit analysis is the main evaluation instrument and the present values of benefits and cost are calculated for the comparative analysis in this study.

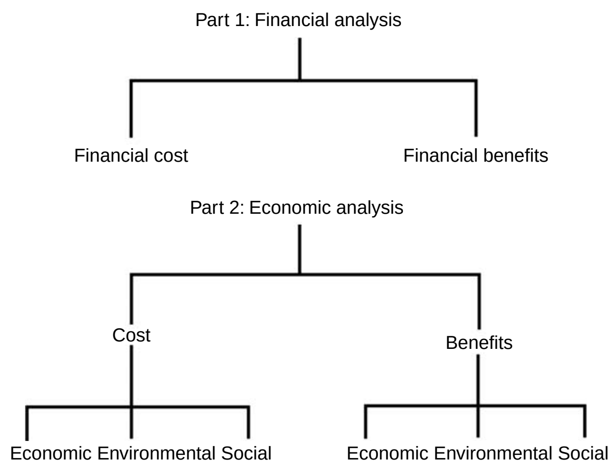

Figure 1 | Two parts of the analysis.

INTRODUCTION OF CASES

Two cases, the Qing project and the BNU project, are chosen for the analysis. They are both located in the city centre of Beijing. The two projects concern grey water reclamation and reuse for toilet flushing and green land irrigation. The Qing project is located in a residential area and serves around 2,500 people. The BNU project is located at a university campus and serves around 30,000 people. The treatment capacity of the Qing project is around 65 m^3 per day and the capacity of the BNU project is 400 m^3 per day. As the wastewater treatment technology of the Qing project is similar to that of the BNU project, it is possible to make a direct comparison between these two projects. All data for the estimation are collected through interviews with the project managers.

FINANCIAL ANALYSIS

The financial cost includes initial investment (defined as V_I), operation and maintenance (O&M) cost (defined as $V_{O\&M}$). All components contributing V_I and $V_{O\&M}$ are shown in Equations (1) and (2), respectively:

$$V_{\mathrm{I}} = V_{\mathrm{B}} + V_{\mathrm{M}} + V_{\mathrm{P}} \tag{1}$$

$$V_{\mathrm{O\&M}} = \sum_{t=1}^{n} \frac{V_t}{(1+r)^t} \tag{2}$$

where V_{B}, V_{M} and V_{P} are the initial costs of buildings construction, electrical and mechanical equipments and pipes, respectively. V_t is the O&M cost occurring in year t; r is the discounting rate; n is the evaluation period (number of years).

According to the publication Chinese Economic Evaluation Parameters on Construction' (2006), the discount rate (r) used for cost benefits studies in China is 8% including the inflation rate. Inflation rates in China for the years 2007 and 2008 are 4.8% and 5.9%, respectively, and the opportunity cost of capital is around 3%. Because few decentralized wastewater reuse systems are operational over a long period in Beijing, the evaluation period (n) is assumed to be 10 years.

The financial benefits of a project are represented by the income for the project, including revenue from reclaimed water charges and subsidises. The project manager of the Qing could obtain revenue from reclaimed water charges since the residents pay a rate for reclaimed water. But the manager of the BNU project does not have revenue from the reclaimed water charges. The reason is that the BNU project serves the students of the university who do not need to pay for consumption of reclaimed water. Subsidy is an important source of income for wastewater reuse projects. Generally the buildings and equipments of decentralized wastewater reuse projects are subsidized by the Beijing municipal government. In some cases, the O&M cost is also subsidized each year.

The ratio of financial benefits to financial cost is the criterion to determine the financial feasibility of the project. If the ratio is larger than 1, the project is financially feasible. Otherwise, the project is not financially feasible. The financial cost, financial benefits and ratio are calculated by Equations (3)–(5), respectively:

$$\mathrm{FC_{PV}} = V_{\mathrm{I}} + V_{\mathrm{O\&M}} \tag{3}$$

$$\mathrm{FB_{PV}} = \sum_{t=1}^{n} \frac{\mathrm{FB}_{\mathrm{r}(t)}}{(1+r)^t} + \sum_{t=1}^{n} \frac{\mathrm{FB}_{\mathrm{s1}(t)}}{(1+r)^t} + \mathrm{FB_{s2}} \tag{4}$$

and

$$R_{\mathrm{FB/FC}} = \frac{\mathrm{FB_{PV}}}{\mathrm{FC_{PV}}} \tag{5}$$

where $\mathrm{FC_{PV}}$ is the financial cost; $\mathrm{FB_{PV}}$ is the financial benefits; $\mathrm{FB}_{\mathrm{r}(t)}$ is the revenue occurring in year t; $\mathrm{FB}_{\mathrm{s1}(t)}$ is the subsidies occurring in year t; $\mathrm{FB_{s2}}$ is the subsidies for initial investment, $R_{\mathrm{FB/FC}}$ is the ratio of financial benefits to financial cost.

ECONOMIC ANALYSIS

All the economic, social and environmental effects caused by decentralized wastewater reuse systems are listed in Table 1, adapted from literature (Hernandez *et al.* 2006). However, it is worth noting that not all the effects listed in Table 1 will be included in the economic analysis. Only the major economic, environmental and social effects are selected and quantified using monetary values. The reasons for the selection of only certain effects and the determination of their monetary values are explained below.

First of all, from the point of view of society, construction, operation and maintenance are seen as consumption of scarce resources, so initial investment and O&M cost are included in the economic cost evaluation, which are the same components contributing the financial cost.

Table 1 | Economic, social and environmental effects

Economic cost	Initial investment
	Operation and maintenance cost
Environmental cost	Noise pollution
	Air pollution
Social cost	Health risk
Economic benefits	Cost saving on constructing pipes
	Cost saving on water distribution
	Cost saving on water purification
	Reuse of pollutants
Environmental benefits	Increase of water availability
	Increase in the level of rivers
	Avoidance of overexploitation of water-bearing resources
Social benefits	Raising social awareness

As there are not traded items in the economic cost and there are not large distortions in market prices of wastewater treatment construction in Beijing, market prices are used for the calculation in this case. Hence the economic cost (defined as V_E) can be obtained by adding the market prices of initial investment (V_I) and O&M cost ($V_{O\&M}$), shown in Equation (6).

$$V_E = V_I + V_{O\&M} \quad (6)$$

Secondly, noise and bad smell could be generated during the wastewater treatment processes. The stench can be eliminated through a ventilation system reducing the impact for the inhabitants, while the noise pollution can not be neglected as noise is difficult to be removed. As the stench does not cause significant effect in this case, air pollution is excluded in the calculation. Only noise pollution is selected to be the factor for the environmental cost analysis.

Valuation of the effects of noise is very complicated. To simplify the determination, we employ the value used in the literature. Liu (1999) finds that the noise pollution cost in Dalian city is around 108 Yuan per person each year. We calculate the noise pollution cost in the current study by converting the noise pollution value of Dalian City. The conversion can be made using the differences of income and consumption between Dalian and Beijing city. According to the Beijing statistical yearbook 2005, the income of Beijing's resident is 1.5 times higher than the income of Dalian's resident. Additionally the ratio of the consumption of Beijing to Dalian is also 1.5. It could be assumed that the noise pollution cost of Beijing is 1.5 times higher than the one of Dalian city. Thus the noise pollution cost per person per year (defined as C_U) in the current study is 162 Yuan. The environmental cost (defined as C_N) can be obtained by multiplying C_U and the number of affected people (defined as N), and is mathematically expressed as:

$$C_N = C_U \times N \quad (7)$$

Thirdly, the quantity of pathogens in reclaimed water treated by these small decentralized plants probably does not reach the official minimum health standards. Human health risks depend on the source of the pathogens, the treatment applied and the exposure route (Ottoson & Stenström 2003). The wastewater reuse projects in this study provide non-potable water for toilet flushing and green lands irrigation. The "spraying irrigation method" which is used by most of the decentralized systems in Beijing, is a typical surface irrigation method. This surface irrigation technique could be negative to human health (Christova-Boal *et al.* 1996). Thus decentralized wastewater reuse systems in Beijing can have negative effects on human health.

Economists use different methods to value health effects, such as contingent valuation methodology and adjusted human capital methodology. Because of inherent limitations, these economic methods have to be applied to big samples with a large amount of data. We use an indirect valuation method to assess the health effects of wastewater reuse. The Disability Adjusted Life Year (DALY) index is taken as a measurement unit for the effect on human health. DALY is an index of health risk, developed by the World Health Organization (WHO) and the World Bank. 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 with no diseases and disabilities (WHO 2007). DALY is used in many studies for measuring health effects. For example, Aramaki *et al.* (2006) find that after building wastewater treatment units, the disease burden of a community changed from 60 DALYs per year to 5.7 DALYs per year (Aramaki *et al.* 2006). In our study, DALY is a bridge to convert the monetary value of health effects from the national level to the scope of a small project. Moreover, the disease diarrhoea is assumed to be the negative health effect caused by wastewater reuse in this study. Diarrhoea is the largest contributor to the burden of water-related disease (OECD 2007).

The social cost (defined as C_S) can be calculated by Equation (8). The origin of such calculation method for the social cost is explained as follow. Through the contingent valuation methodology, the World Bank values the total health cost (defined as C_M) caused by water pollution in China, which is about 14.22 billion Yuan each year (World Bank 2007). In terms of the figure of the WHO report (2004), the total estimated DALYs (defined as M) caused by diarrhoea is 5055,000 DALYs each year.

The DALY cost rate (C_M/M) is calculated to be 2,813 Yuan per DALY per year. The product of DALYs rate (defined as R) and population number (defined as K) gives the total DALYs of Beijing. As a result of missing data, the DALYs rate of Beijing (R) is determined by the DALYs rate of China, which is 389×10^{-5} DALYs per person (WHO 2004). The registered permanent population living in Beijing central district is 2.25 million. It is supposed that the DALYs of Beijing resulting in diarrhoea is caused by total reclaimed wastewater. Accordingly the probability of DALYs due to irrigating reclaimed water on green land (P_1) could be represented by the ratio of reclaimed water amount for green area irrigation to the total reclaimed water amount in Beijing. P_2 denotes the probability of DALYs due to irrigating the green land of the project. Since large area of green land surface could increase the infection of diarrhoea, P_2 is represented by the ratio of the green land area in the project to total green land surface of the Beijing city centre.

$$C_S = \frac{C_M}{M \times R \times K \times P_1 \times P_2} \quad (8)$$

Fourthly, as listed in Table 1, the economic benefits generally include cost saving on constructing pipes, cost saving on water purification and distribution, and reuse of pollutants. Being the conventional systems, centralized wastewater reuse systems have been applied in Beijing for many years, which need huge investments on pipes construction for reclaimed water distribution due to the long distance between centralized plants and users. Compared with centralized wastewater reuse systems, decentralized systems require shorter reclaimed water distribution pipes so that the huge cost of pipes construction can be saved. As the capacity of a decentralized plant is usually limited, the cost saving on water purification and distribution is so small that it can be ignored in the current analysis. Generally the pollutants of decentralized wastewater reclamation are not reused in the Beijing urban area, so the benefit of reuse of pollutants is not considered in the study. As a result, only the cost saving on pipes construction is selected for the economic benefits analysis. Cost saving on water purification and distribution, and reuse of pollutants are neglected in the economic benefits analysis.

Figure 2 | Location of Beijing centralized wastewater reclamation plants and the two projects studied.

There are in total five large centralized plants in Beijing: Gao beidian, Fang zhuang, Wu jia cun, Qing he and Jiu xianqiao. The Fangzhuang wastewater reclamation plant shown in Figure 2 is the closest to the Qing project, and the Jiu Xian Qiao plant is the closest to the BNU project. We assume that the reclaimed water would be provided by the closest centralized plant if there is no on-site project. Hence the economic benefits of avoiding constructing pipes (defined as B_L) can be calculated as

$$B_L = C_L \times L \quad (9)$$

where C_L is construction cost per metre pipe and L is the distance between the closest centralized plant and the studied projects.

According to interviews with officials of the Beijing drainage group, the value of C_L is between 2,000 and 20,000 Yuan/m. We take the least unit cost value 2,000 Yuan/m and the shortest distance between the on-site project and the closest big plant for the estimation.

Fifthly, more and more "new water" is created through reusing wastewater, decreasing the stress on water resource depletion. The increase of water availability is a crucial environmental benefit, especially for a city like Beijing which has water scarcity. However, on the basis of the two projects studied, the actual increase in the river level and reduction of the overexploitation of water-bearing resources cannot be recognised. For simplicity the current study assumes that only the "increase of water availability" makes major contributions to the environmental benefits.

The shadow price of Beijing water resource is estimated to be around 3 Yuan/m^3 (Liu & Chen 2003). The environmental benefit (defined as B_E) of increase of water availability can be calculated by Equation (10):

$$B_E = C_E \times E \tag{10}$$

where C_E is unit water monetary value and E is the amount of reclaimed water.

Finally, it is still a long way to increase the public awareness on utilizing reclaimed water. Normally awareness improvement could be reached through various public education and advertisement campaigns. The introduction of decentralized wastewater reuse systems is a method to enhance the awareness concerning water saving so that cost is saved on awareness rising campaigns. It is assumed that the educational effect of a decentralized plant is the same as the effect of a public campaign. The cost saving on campaigns can be regarded as the social benefits (defined as B_S) of the wastewater reuse projects. This can be determined by total expenditure on public awareness raising campaign (defined as S) and the ratio of number of users to total population in Beijing (defined as Q) as expressed in Equation (11):

$$B_S = S \times Q \tag{11}$$

The average cost of public campaign (S) in water sector in Beijing is 2780,000 Yuan/year (DPP 2001).

All the parameters used to determine the monetary values of economic, environmental and social effects are summarized in Table 2.

The ratio of benefits to cost (defined as $R_{B/C}$) is used as the criterion for economic feasibility. If $R_{B/C} > 1$, the project is economically feasible. If $R_{B/C} < 1$, it means the project is not economically feasible. The cost (C_{PV}), benefits (B_{PV}) and the ratio of benefits to cost ($R_{B/C}$) are calculated by Equations (12), (13) and (14), respectively:

$$C_{PV} = V_E + \sum_{t=1}^{n} \frac{C_N}{(1+r)^t} + \sum_{t=1}^{n} \frac{C_S}{(1+r)^t} \tag{12}$$

$$B_{PV} = B_L + \sum_{t=1}^{n} \frac{B_E}{(1+r)^t} + \sum_{t=1}^{n} \frac{B_S}{(1+r)^t} \tag{13}$$

and

$$R_{B/C} = \frac{B_{PV}}{C_{PV}} \tag{14}$$

It is assumed that the values of environmental cost (C_N), social cost (C_S), environmental benefit (B_E) and social benefit (B_S) in each year do not changed during the evaluation period.

Table 2 | Summary of the parameters on determination of cost and benefits

Parameter	Definition
V_I	Initial investment (Yuan)
$V_{O\&M}$	Operation and maintenance cost (Yuan)
V_E	Economic cost (Yuan)
C_U	Unit cost of noise effect (Yuan per person per year)
N	Affected user number (persons)
C_N	Environmental cost (Yuan/year)
C_M	Total health cost (billion Yuan/year)
M	Total DALYs caused by water (DALYs/year)
R	DALYs rate (DALYs per person per year)
K	Population of Beijing (million persons)
P_1	Probability of DALYs due to irrigating reclaimed water on green land (%)
P_2	Probability of DALYs due to irrigating the green land of the project (%)
C_S	Social cost (Yuan/year)
C_L	Unit cost on pipes construction (Yuan/m)
L	Distance between closest centralized plant and users (m)
B_L	Economic benefit (Yuan)
C_E	Water monetary value (Yuan/m^3)
E	Amount of reclaimed water (m^3/year)
B_E	Environmental benefit (Yuan/year)
S	Total spent on public awareness raising campaign (Yuan/year)
Q	Ratio of number of users to total population (%)
B_S	Social benefit (Yuan/year)

RESULTS

Table 3 presents the results of the financial analysis of both projects. It is shown that total initial investments

Table 3 | The financial analysis

	Qing project	BNU project
Financial cost		
Initial investment (Yuan)		
Buildings	40,000	100,000
Equipments	260,000	500,000
Pipes	2600,000	3100,000
Sub-total	2900,000	3700,000
O&M cost (Yuan/year)		
Electricity	45,638	131,765
Chemical	7,000	10,000
Maintenance	1,200	12,235
Personnel	27,000	46,000
Sub-total	80,000	200,000
Financial benefits		
Revenue (Yuan/year)	21,000	0
Subsidies (Yuan)	300,000	1942,000

are 2.9 million Yuan in the Qing project and 3.7 million Yuan in the BNU project. Although the treatment capacity of the BNU project is almost 7 times larger than that of the Qing project, the difference in the initial investment values between two projects is not significant.

In the O&M cost, electricity cost is much higher than the other O&M costs. For example, the electricity consumption of the BNU project each year is around 131,765 Yuan. The personnel cost being the second largest cost in O&M, is only one third of the electricity cost. The electricity cost depends on the capacity of plant and the unit cost of energy. Hence the capacity of plant and the unit cost of energy have significant influences on the O&M cost of a wastewater reuse project.

For the sake of comparative analysis, the present values of all effects in the economic analysis are calculated and listed in Table 4. The environmental cost of the Qing project is 32,611 Yuan whereas the environmental benefits of the Qing project are 402,605 Yuan. Thus the environmental benefits are 12 times larger than the environmental cost. For the BNU project, the environmental benefits are 260 times larger than the environmental cost. This implies that the decentralized system is relatively environmental friendly although it causes some noise pollution.

Table 4 | The economic analysis

	Qing project	BNU project
Cost		
Economic cost (Yuan)	3437,000	5042,000
Environmental cost (Yuan)	32,611	10,870
Social cost (Yuan)	13,212	13,212
Total	3482,823	5066,082
Benefits		
Economic benefits (Yuan)	16000,000	24000,000
Environmental benefits (Yuan)	402,605	2818,000
Social benefits (Yuan)	21,411	290,000
Total	16424,016	27108,000

The economic benefits are represented by the value of cost saving on constructing pipes, accounting for around 90% of total benefits. In centralized systems, the reclaimed water distribution pipes would have to be built in existing urban areas through demolition and relocation, leading to extremely high cost of pipes construction. This pipes construction cost could be effectively saved by decentralized systems. In the Qing project, cost saving on constructing pipes is 16 million Yuan whereas initial investment of the Qing project is only 2.9 million Yuan. In the BNU project, cost saving on pipes is 24 million Yuan and initial investment of the BNU project is 3.7 million Yuan. It implies that the funding of pipes construction for distributing reclaimed water could finance the investments of around 5 or 6 decentralized plants.

Table 5 shows the results of financial and economic feasibility analysis. In the economic analysis, the ratio of benefits to cost of the Qing project is 4.7 which is larger than 1. Similarly, the ratio of the BNU project is also larger than 1. This shows that both Qing and BNU projects are economically feasible, which indicates that decentralized wastewater reuse systems have positive effects on society. From the point of view of the government, decentralized

Table 5 | The results of financial and economic feasibility

	Qing project	BNU project
Financial analysis (ratio of financial benefits to financial cost: $R_{FB/FC}$)	0.13	0.38
Economic analysis (ratio of benefits to cost: $R_{B/C}$)	4.7	5.4

wastewater reuse systems deserve to be promoted. However, in the financial analysis the ratios of financial benefits to cost of both projects are smaller than 1, which implies that the two projects are not financially feasible. Thus the project managers would prefer not to operate the wastewater reuse systems and the systems may not remain operational in the long term.

DISCUSSION

For the sake of systematic analysis, a coding form (Table 6) is made based on the method of meta-analysis (Lipsey & Wilson 2001). The information and evaluation results are codified either by 0 or 1. Table 6 shows that the Qing project has a different score as the BNU project only at item A.

The scores on item A imply that the BNU project has a much larger capacity than the Qing project. It was found that there is economic scale in wastewater reclamation and reuse, namely the unit cost decrease when the system scale becomes larger (Yamagata *et al.* 2003; Friedler & Hadari 2006). Economies of scale imply that small decentralized treatment systems may have a higher unit cost than the centralized system. The unit O&M cost of the project Qing is higher than that of the BNU project. However, no matter the scale, both projects studied show the same results: economically feasible but not financially feasible. Hence the economic feasibility or financial feasibility is not related to the scale of operation according to this study.

The scores on item B indicate that the unit O&M costs of two projects are higher than the rate for reclaimed water.

Table 6 | Codified data for two projects

	Qing project	BNU project
A. Economic scale	0	1
B. Unit O&M cost	1	1
C. Total cost recovery	0	0
D. Financial feasibility	0	0
E. Economic feasibility	1	1

A, 0: small; 1: large; B, 0: unit O&M cost is smaller than reclaimed water rate; 1: unit O&M cost is larger than reclaimed water rate; C, 0: total cost is not recovered; 1: total cost is recovered; D, 0: not financially feasible; 1: financially feasible; E, 0: not economically feasible; 1: economically feasible.

The unit O&M cost of the Qing project is around 3.8 Yuan/m^3 and the unit O&M cost of the BNU project is around 1.5 Yuan/m^3. The reclaimed water rate lies at 1 Yuan/m^3 which is much lower than the O&M cost. The rate for reclaimed water determines the financial benefits of a project and the low rate affects the cost recovery in a negative way. Item C shows that total cost of both projects can not be recovered financially. The low rate of reclaimed water is an important factor that does not contribute to cost recovery, thereby leading to the decentralized wastewater reuse system not being financially feasible.

As the quality required for reclaimed water is lower than the quality required for drinking water, there is a misconception that the cost of reclaimed water is lower than that of drinking water. Although the cost of tertiary treatment for reclaimed water is low, the cost of reclaiming wastewater in an entire treatment process is high (Ogoshi *et al.* 2001; Angelakis *et al.* 2003; Borboudaki *et al.* 2005). For example, the study of Ogoshi *et al.* (2001) indicates the cost of reclaimed water in the Fukuoka City of Japan is 2.01 US dollar/m^3, while the cost of drinking water is only 1.88 US dollar/m^3. Following those findings in literature, it is assumed that the cost of reclaimed water in Beijing is also higher than the drinking water. The price of reclaimed water is fitted as 1 Yuan/m^3 by the government whereas the price of drinking water is 3.7 Yuan/m^3. This implies that the current rate of 1 Yuan/m^3 on reclaimed water does not reflect the real cost.

It is concluded that economic scale is not the reason for not being financially feasible. The low rate charged for reclaimed water is the crucial factor why decentralized water reuse projects are not financially feasible. The reclaimed water rate is lower than the actual O&M cost and does not reflect the real cost of reclaimed water.

CONCLUSIONS

The present paper evaluates the decentralized wastewater reuse systems in Beijing through an integrated financial and economic feasibility analysis. The financial analysis is made from the point of view of project manager, while the economic analysis is from the point of view of society.

The major economic, environmental and social effects of the projects are all considered in the economic analysis.

The analysis indicates that decentralized wastewater reuse systems are economically feasible. It means the systems have positive effects on society. Thus, from the point of view of government or society, the decentralized wastewater reuse systems are worth to be promoted.

However, decentralized wastewater reuse systems are not financially feasible. This implies that there are serious financial problems in the systems. The low rate charged for reclaimed water is the key reason for the systems not being financially feasible. From the project manager's perspective, 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 decentralized wastewater reuse systems should be on the political agenda in the future (Angelakis *et al.* 2003). It would require subsidies unless realistic pricing policies for water are introduced.

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