Real Option Approach to Sharing Privatization Risk in Underground Infrastructures

Taeil Park[1]; Byungil Kim[2]; and Hyoungkwan Kim[3]

Abstract: Over the last two decades, more than 100 water and sewer systems have been sold or leased to private entities in the United States due to shortages in government funding. While privatization has allowed governments to relieve their financial difficulties, users have taken on such risks in the form of high rates and poor service. When compared to other infrastructures, water and sewer systems generate somewhat stable revenue. However, water and sewer systems are also characterized by the hardly predictable operation and maintenance (O&M) expenses. Such characteristics make it difficult to devise a proper contract that satisfies the interested parties, such as governments, private operators, and users. By investigating the deficiencies of previous privatization contracts, this study presents a real option–based contract model to ensure appropriate risk sharing between private entities and governments. Simulation results based on three different O&M expense scenarios (best, moderate, and worst) indicate that the proposed contract model would provide a win-win situation for all related parties.
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Introduction

Public-private partnerships (PPPs) have often been used to alleviate the financial burdens of governments involved in infrastructure projects. Based on project delivery methods, PPPs can be categorized as build-operate-transfer (BOT), design-build-operate (DBO), design-build-finance-operate (DBFO), and build-own-operate (BOO) (Miller 2000). The technique most often used for PPPs is the BOT approach (Ho and Liu 2002; Liu and Cheah 2009). Since infrastructure privatization is often associated with excessive uncertainty in both the future performance of the system and the corresponding cash flows, host governments include various forms of subsidies in the agreements in order to attract the private sector (Klein 1997; Dailami and Klein 1998). Subsidies or incentives could be provided in the form of guarantees specified by the contracts, e.g., minimum revenue guarantee, minimum traffic guarantee, and a cost ceiling.

The successful realization of PPP projects begins with proper risk sharing between the involved parties. In order to satisfy the demands of both the private entity and the government, it is important to distribute financial risks evenly through contractual agreements. From the perspective of the government, a guarantee agreement represents contingent liabilities imposed on the public sector that could lead to a substantial budget deficit in the future. In order to avoid a possible one-sided contract, the government should establish complementary agreements that counterbalance the value of the guarantee. An example of such an agreement is the obligation of the private entity to pay back a certain portion of the revenue to the government if the revenue scale is considered too excessive.

While there have been many attempts to evaluate the financial viability of infrastructure projects, most researchers have investigated toll road projects and few works have been conducted for water and sewer infrastructures. In toll road PPP projects, the principal uncertainties mostly pertain to the revenue rather than to the O&M expenses. Thus, arrangements for the revenue, such as a minimum revenue guarantee (MRG) and a maximum revenue limit (MRL, also known as a revenue cap), could be sufficient to cover the major portions of underlying risks in the projects. This approach could be properly effective when O&M costs are relatively predictable and stable. However, this is not the usual case for water and sewer infrastructure projects, although there are some exceptional cases with the drastic increase and decrease of water usage, such as Seattle in Washington and Dallas in Texas in the 1990s (Rockaway et al. 2011).

In water and sewer systems, the major income factors for revenue are the water and sewer tariff and the number of users. In this sense, the cost structure of water and sewer systems is similar to that of toll roads. However, there is a significant difference between the two cases. The users of toll roads may utilize detours to avoid high-rate toll roads, while no such alternatives exist in water and sewer systems. This means that the number of users may be easily predicted in water and sewer systems, but possibly not in toll roads. Conversely, although it is possible to predict future O&M costs for water and sewer systems based on the historical data, the total O&M costs for the long concession period are hardly predictable; the costs are severely influenced by technical and socio economic factors, whose impacts are hardly measurable. The system performance is directly related to the O&M cost (McHaney 1992; Zaghloul and Karaa 1995) and different levels of deterioration can yield a range of system performances under different

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surrounding conditions such as investment plans, management skill, weather conditions, pipe properties, and soil conditions. These future uncertainties are aggravated by the socio-economic factors such as inflation, relevant laws and regulations, and O&M market conditions. Thus, major uncertainties for the concession of water and sewer systems arise from the O&M cost. This characteristic makes it difficult to adopt MRG and MRL in water and sewer systems because such approaches do not provide a sufficient level of incentive for the system operator (the private entity) to be efficient in O&M.

Considering the importance of water and sewer systems to the public, privatization contracts should reflect the public interests, i.e., they should have a reasonable tariff and a rational rate of tariff increase. The impact of the water and sewer tariff on users is much more significant than, for example, that of the toll fee in the sense that water and sewer systems are essential for daily life. However, most cases of failure in water and sewer privatization arise mainly from a large increase in the tariff after the privatization of the system (Food and Water Watch 2010). An annual average of 15% (adjusted for inflation) water rate increase was observed in the 10 largest sales and concessions in the United States over an average of 12 years after privatization (Food and Water Watch 2010). In several systems, litigation for the nationalization of a privatized sewer system is still ongoing (Food and Water Watch 2010). Consequently, the primary objective of this study is to propose a new contract model that leads to a win-win situation for all related parties, i.e., private entities, governments, and even users. The model is based on the concept of a real option for fair and reasonable risk sharing.

Literature Review

With the growth of infrastructure privatization, the need for techniques to evaluate private investment in public infrastructures has dramatically increased. Traditionally, discounted cash flow methods, such as the net present value (NPV) method and the internal rate of return (IRR), have been widely used as project evaluation techniques due to their simplicity. However, these schemes do not properly account for the impact of managerial flexibility on the value of the projects. The future rewards of infrastructure investments are frequently uncertain and project risk can change with new information. Thus, the NPV underestimates the value of flexibilities that change operational strategies in response to a dynamic environment.

A real option is the right, but not the obligation, to take business action in investments. A real option is an extension of financial option theory to the real world in order to evaluate opportunity costs. Recently, many researchers have expanded the concept of a real option to the field of infrastructure systems. Rose (1998) used Monte Carlo simulation methods to estimate the concession period and the value of deferral concession payment option of the Transurban City Link project. Ho and Liu (2002) proposed a BOT option valuation model to evaluate the financial viability of government guarantees and negotiation options for privatized infrastructure projects. The researchers applied the model to an airport terminal project to demonstrate its advantages over the conventional NPV method. Ho and Liu (2003) presented a quantitative valuation model to evaluate technology investments and establish an optimal investment plan for emerging architectural/engineering/construction (AEG) technologies. Zhao and Tseng (2003) used a trinomial lattice model and stochastic dynamic programming to obtain the value of an expansion option in public parking garages. Garvin and Cheah (2004) used a binomial model to strategically assess the value of a deferment option for the Dulles Greenway project in northern Virginia. Cui et al. (2004) emphasized the importance of a warranty option in federal highway projects by describing the pros and cons of the warranty contract. Cheah and Liu (2006) estimated the value of governmental subsidies, such as repayment and guarantee options, by applying a Monte Carlo simulation to a case study of the Malaysia-Singapore Second Crossing toll road. Chiara et al. (2007) evaluated a guarantee option for a hypothetical toll road project using a multi-least-squares Monte Carlo simulation. Alonso-Conde et al. (2006) applied Monte Carlo simulation to value the guarantee agreements of a deferred payment option and a cancel the concession early option in the toll road Melbourne CityLink Project. Cui et al. (2008) investigated the price of a warranty for New Mexico Highway 44 and assessed the value of a ceiling clause option using a binomial lattice model. Brandao and Saraiva (2008) developed an innovative real option framework subject to minimum traffic guarantee instead of conventional minimum revenue guarantee and investigated the impact of the different level of guarantee on the government exposure. Shan et al. (2010) applied collar options to manage revenue risks for losses and profits of contracting parties by determining the exercise price of the options in a real toll road project.

As indicated above, the real option theory has greatly advanced the framework of infrastructure projects in that it enables the valuation of managerial flexibilities in the implementation of the project and the proper risk sharing among the contracting parties. However, most researchers have focused on pavement and not on water and sewers. In this study, an innovative real option-based contract model suitable for water and sewer systems is proposed. The concept of a maximum revenue limit (MRL) and maximum expense limit (MEL) were applied instead of a conventional revenue cap and MRG option so as to stimulate the PPP participation of private entities in water and sewer systems. The MEL represents the total amount of O&M expenses that must be covered by the private entity. Any additional O&M expense over the limit becomes a liability imposed on the government. In this way, the private entity can be protected from the risk of O&M expense increase.

Three factors differentiate the combination of an MRL and MEL option used in this study from the revenue cap and MRG option employed in previous research. First, the primary cause of uncertainty for MRL and MRG options was identical to the traffic volume in previous studies, while the main contributors to the uncertainty of MRL and MEL in this study are the price index that is tied to the tariff and the system behavior (including O&M expenses), respectively. Second, the MRG option would be executable on a yearly basis, while the MEL option is exercised at the end of concession period, so as to motivate efficient O&M operation. Third, the revenue cap and MRG are a call option and put option, respectively, while both the MRL and MEL are call options.

Probability-Based Risk Sharing Using Real Option Analysis

Privatization of a Water and Sewer System

The privatization of a water and sewer system is quite different from that of a toll road because a sewer and water system has a different cost structure and user impact. According to a Food and Water Watch analysis (2010), at least 17 possible sales or concession deals for a water and sewer system were stopped between 2007 and 2010 due to strong public opposition. The primary reason for the opposition was the prerecognition of a possible rate increase, which has occurred in many cases of privatization in the

United States. In contrast, the water and sewer tariff is the main profit element for private entities, and thus they are not willing to buy or lease the systems unless they see a sufficient potential for profit with current and future rates. Therefore, it is important to develop a contract model that can address the conflicting interests of public and private entities.

Cost Structure of a Water and Sewer System

The cost structure of a water and sewer system relies heavily on the rate; the private entity would not give up the right to determine the sewer tariff without governmental supports. In general, the government has two options for its subsidies. One option is direct revenue support, which can be achieved with a minimum revenue guarantee (MRG), while the other is indirect cash flow support, which can be accomplished with a maximum expense limit (MEL). Technically, a MEL agreement is a type of guarantee option that represents the potential risks to the government. However, from the private entity's point of view, a MEL is more acceptable than an MRG in water and sewer infrastructure because O&M expenses are more difficult to predict than revenue. More importantly, when the O&M costs increase drastically, an MRG could lead to a possible rate hike in the near future, while an MEL agreement could be executed with a steady increase in the sewer tariff. This is because the only variable which could be controlled under an MRG is the sewer tariff and thus there would be a high likelihood for the rate hike in case of the drastic O&M cost increase. Therefore, the public would be more willing to accept the privatization of the system with an MEL agreement. As a result, although rate schedules or indexing methods could work as bumper for the rate hike, the MRG is less effective in limiting the rate increase than the MEL. In addition, the private entities may not be willing to participate in the project with strong contractual provisions for rate schedules or indexing methods, because they could face a bigger uncertainty of the project's return.

O&M costs and increase rate for a water and sewer system vary considerably depending on the market prices (labor cost, energy cost, equipment cost, materials cost, and interest rate) and surrounding conditions (soil conditions, locations, deterioration levels, and population). In addition, future O&M costs could be significantly reduced if the overall condition of the system is improved through extensive replacement and rehabilitation (R&R) activities. Thus, if the government provides an MEL option to the contractor that can be executed on a yearly basis, most private entities would concentrate on the R&R activities in the early operation years in order to recover the majority of the cost with the MEL option and reduce the expected future O&M costs. In this sense, it can be inferred that the MEL option makes it easier for private entities to take advantage of the agreement rather than maximize profits through effective and efficient system O&M. Consequently, this could prevent the O&M companies from adopting an optimal R&R investment strategy during the concession period.

Numerical Projection of Operation Scenarios for the Water and Sewer System

Three different operation scenarios were developed based on cost data from a project report called "Optimization of collection system maintenance frequencies and system performance" (Black and Veatch 1999). The report summarized maintenance cost data collected from 42 agencies across the United States. The data included the region, sewer length, population, number of pumping stations, and system maintenance costs over four time periods (pre-1970, 1970–1979, 1980–1989, and 1990–1996). Based on the two most recent time periods, three operation scenarios were developed—best, moderate, and worst case. The costs were adjusted with the Engineering News Record (ENR) construction cost index so as to capture the time value of money.

Shown in Fig. 1 are the different O&M expense scenarios based on the practical assumption for sewer system privatization displayed in Table 1. The same system shows markedly different performances under different surrounding conditions. Because the usual deterioration curve of the sewer system resembles a negative exponential curve, the expense cost could increase exponentially during the system life cycle. Note that different increase rates (3.6%, 4.4%, and 6.2%) were selected based on the cost data reported in the Black and Veatch report (1999) to represent the three O&M expense scenarios (best, moderate, and worst, respectively).

Methodology and Theoretical Background

One of the objectives of this study is to determine a reasonable exercise value for a MEL agreement. Since the exercise value of the MEL controls the total amount of risk the government undertakes, fixing the exercise value is important in order to avoid a lopsided contract. The MRL option is exercised when the private entity achieves a rate-of-return higher than the exercise value of the minimum attractive rate of return (MARR) specified by negotiation. The MRL should be exercised on a yearly basis for the water and sewer system so as to prevent an annual rate hike.

The MRL is a call option; the government has the right to call the surplus cash beyond the MRL. The condition of surplus cash (SC) is illustrated in Fig. 2. As evident in Fig. 2, the surplus cash has value only when the IRR exceeds the exercise value of MARR specified by the contract. Since this study assumes that a risk premium of the project is reflected in the MARR, the surplus cash can be discounted using the risk free interest rate. Accordingly, the option value of the MRL is estimated as follows:

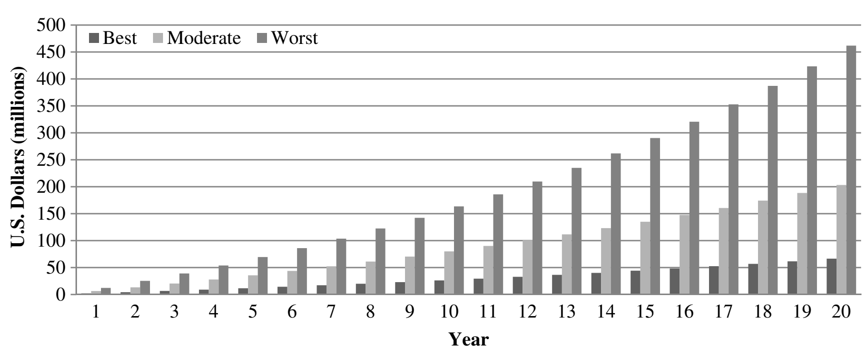

Fig. 1. O&M expense scenarios for the best, moderate, and worst cases

Table 1. Basic Assumption for Sewer System Privatization

Assumptions	Comments
Population served (200,000)	Triangular distribution is used. Minimum, likeliest, and maximum values are 180,000, 200,000, and 220,000, respectively (as of 2005).
Population growth rate (0.01/year)	Triangular distribution is used. Minimum, likeliest, and maximum values are 0, 0.01, and 0.015, respectively (as of 2005).
Initial sewer tariff [$3/2,831.5 L (748 gal.)]	Triangular distribution is used. Minimum, likeliest, and maximum values are 2.4, 3.0, and 3.6, respectively (as of 2005).
Sewer tariff increase rate (0.05/year)	Triangular distribution is used. Minimum, likeliest, and maximum values are 0.04, 0.05, and 0.06, respectively (as of 2005). Government set the sewer increase rate to the price index so as to prevent public opposition. The minimum and maximum values represent the negotiation range.
Miles of sewer [1,448.4 km (900 mi)]	Average value of the cities employed in the analysis using the Black and Veatch report (1999) data.
Sale price (20,300,000)	Calculated from the moderated case of cash flow with a 10% interest rate. The payment was made in 2004.
MARR (25%)	The figure is assumed for the Monte Carlo simulation, and it can be negotiated between contracting parties.
Risk-free interest rate (4.5%)	Found from the US treasury 20-year interest rate as of 2005.
Initial O&M cost of best, moderate, and worst case ($3,299, $7,278, and $13,656, respectively)	The figures are obtained from 20-year sewer operation data from the EPA report (all figures are adjusted to 2005 by the construction cost index).
O&M cost increase rates for best, moderate, and worst case (0.036, 0.044, and 0.062, respectively)	To capture the feature for the deterioration of the sewer system, different rates are used; the deterioration curve resembles a negative exponential curve. The same system shows completely different performances under different surrounding conditions.
Analysis period (20-year operation)	Average age of the system is around 30 years. Since the usual service life of a sewer system is 50 years, the estimated remaining service life was assumed to be 20 years.

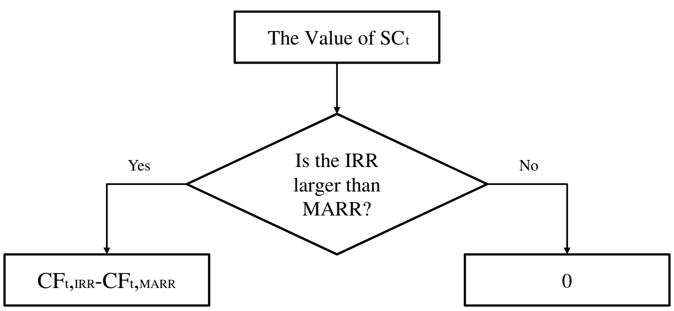

Fig. 2. Illustration of the surplus cash condition

$$\text{Option value of MRL} = \sum_{t=1}^{\text{Period}} \frac{\text{SC}}{(1 + r_f)^t} \qquad (1)$$

where r_f = the risk-free interest.

In this study, the exercise value was established based on the MARR because it reflects both the revenue and O&M expense simultaneously. The value of MARR could be chosen based on the contractual conditions and negotiation. The MEL is also a call option; the private entity has the right to call the guaranteed loss beyond the agreement.

It is necessary to thoroughly define the best, moderate, and worst case scenarios. The MRL is generally executed when the system is in the best case, while the sale or lease price of the system could be determined by the value created in the moderate case. The MEL is activated in the worst case. Thus, to properly share the risks associated with projects, the expected amount of incoming and outgoing cash flow from the MEL and MRL should be balanced in a probabilistic manner. Some of these concepts are illustrated in Fig. 3. As inferred from Fig. 3, both options are call options, because the payoffs of the options decrease as the exercise price become bigger. In addition, this study is predicated on the assumption that the enhanced value from the MRL (A_1) should be equal to the reduced value from the MEL (A_2). A Monte Carlo simulation was used to estimate the revenue cash flow for each year of the system life cycle. The surplus cash flow for each year was then calculated from a comparison with the cash flow generated with the MARR. The option value of the MEL was calculated through the marketed asset disclaimer (MAD) approach whose concept was discussed and utilized by many previous researches (Trigeorgis 1996; Copeland and Antikarov 2001; Garvin and Cheah 2004; Garvin 2005; Cui et al. 2008; Schneider et al. 2008). The uncertainties for the future O&M costs are caused by public risks as well as private risks, and it is difficult to completely classify the risks into the right category. The MAD approach was adopted, since the approach is reported to be applicable to both public and private risks (Schneider et al. 2008; Leung 2008; Karamitos 2009;

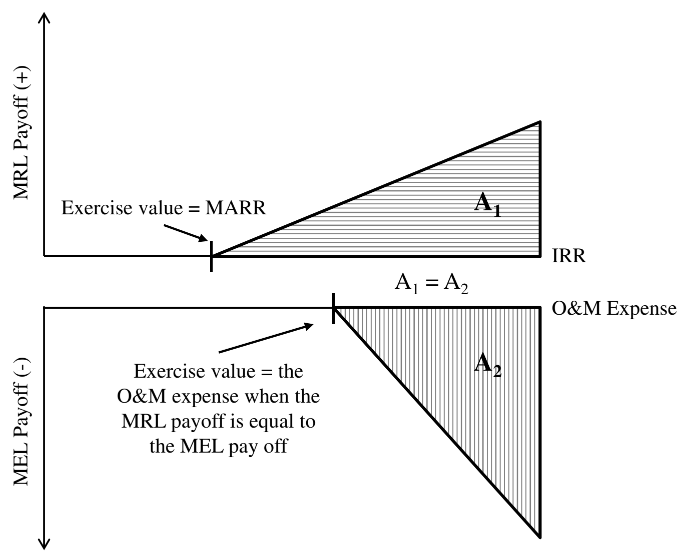

Fig. 3. Balance of MRL and MEL payoffs

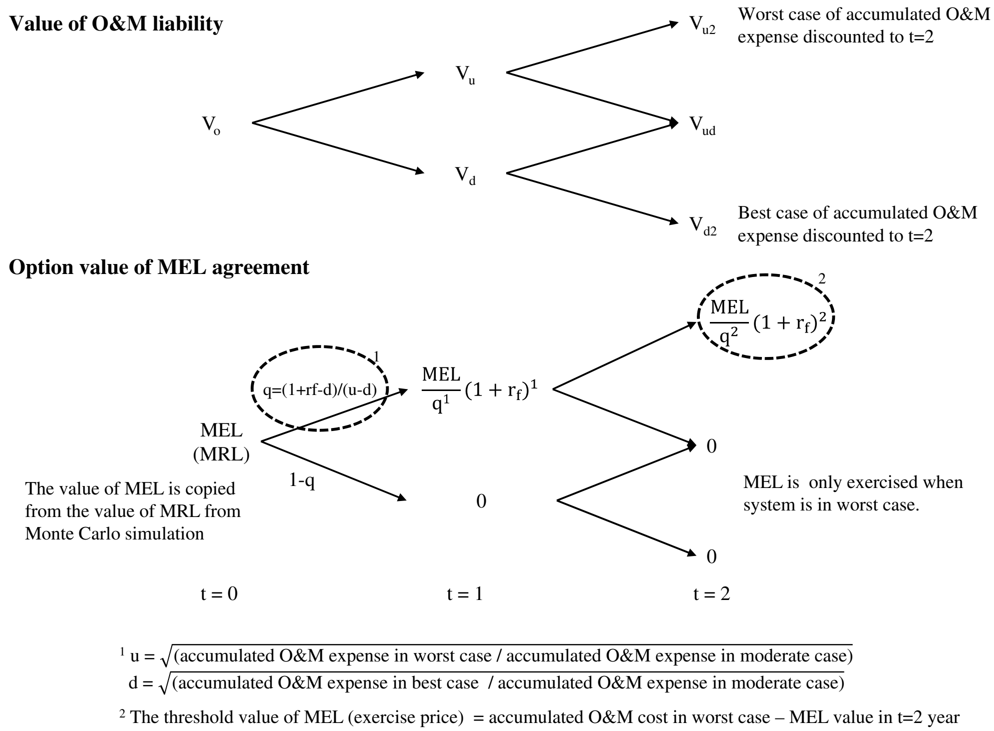

Fig. 4. Procedures for fixing the exercise price of the MEL

Guj and Chandra 2012). The specific procedures for fixing the exercise value of the MEL are illustrated in Fig. 4.

As shown in Fig. 4, the option value of the MRL estimated from the Monte Carlo simulation was used as the initial option value of the MEL in the binomial model. The risk-neutral probability of the rise and fall of the binomial lattice model could be reasonably estimated from the changes in the O&M liabilities imposed on the private entity. At the time of signing the contract, the most likely initial O&M liability (V_o) was the moderate case of the accumulated O&M expenses discounted back to the $t = 0$ year. This assumption was acceptable because if a private company sold the 20-year warranty for O&M to the government, the price of the warranty would be determined based on the prediction of the accumulated O&M expenses in the moderate case. This number could be expanded to the accumulated O&M expenses of the worst case and reduced to the accumulated O&M expenses of the best case after 20 years of operations. Thus, the up movement (u) could be estimated from the ratio of the accumulated O&M expenses in the worst and moderate cases. Using the same reasoning, the down movement (d) could be computed from the ratio of the accumulated O&M expense in the best and moderate cases. From these numbers, the risk-neutral probability of the rise and fall of the binomial lattice model could be computed. Consequently, the exercise value of the MEL in the $t = 2$ year could be obtained by subtracting the option value of the MEL in the $t = 2$ year from the accumulated O&M expenses in the worst case discounted back to the $t = 2$ year.

Case Study for Application of the Contract Model

In the case study under consideration, the government decided to sell a sewer system to a private entity. The contract and corresponding payment were established in 2003 and 2004, respectively, and the system would be operated by the private entity in 2005. In order to prevent public opposition and attract the interest of private entities, the government included special agreements in the contract. The agreements were the maximum revenue limit (MRL), the maximum expense limit (MEL), and a stable sewer tariff increase. In 2003, the government wanted to evaluate the feasibility of the project and determine the option value of each clause. The basic assumptions for the privatization, including the MRL and MEL, are summarized in Table 1. The assumptions were analogized from a typical sewer system case in the Black and Veatch report (1999).

For a typical sewer system, revenue is mainly determined from the sewer tariff and the population. The daily usage of a sewer is usually assumed to be 94.6 L (25 gal.) per person (MWRA 2006; NYCEDC 2008). Thus, the approximate revenue could be reasonably estimated by multiplying the population, daily usage, and sewer tariff. Combined with the O&M cost scenarios, different operation scenarios and corresponding cash flows were obtained; the results are shown in Fig. 5. The revenue was assumed to have the same projection in the three cases because all key variables in the revenue were relatively stable. Thus, the O&M expense represented the difference in the operation scenarios.

For the calculation of the surplus cash (SC) flows, a geometric gradient series cash flow was first created to represent the cash flow with the MARR, which would be determined by the contracting parties' negotiation. The geometric gradient series was used to realistically model the compound growth of the net income of the project. Another cash flow was then generated using the Monte Carlo simulation with the best operation scenario. Since the MRL option was designed to be exercised only in the best case, the best scenario with the minimum O&M costs was used for the simulation. As aforementioned, the surplus cash (SC) flow was determined by subtracting the MARR-based cash flow from the simulated cash flow. Finally, the value of the MRL was estimated by summation of the discounted surplus cash (SC) flow during the concession period.

The simulation results are summarized in Table 2. Considering the low value of skewness and the fact that the mean and median

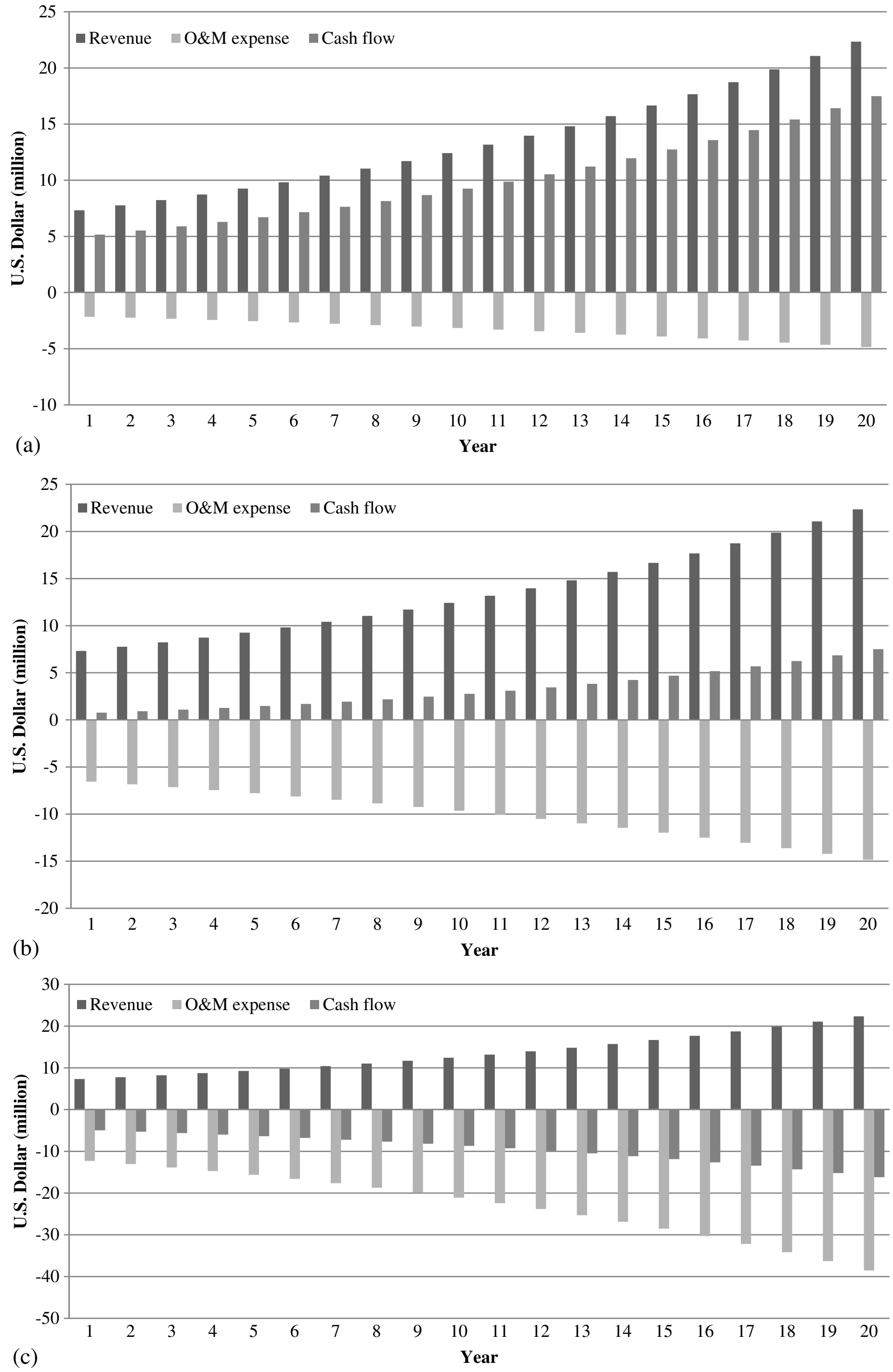

Fig. 5. Projection of different operation scenarios: (a) best operation scenario; (b) moderate operation scenario; (c) worst operation scenario

values were quite close to each other, either the mean or median values could be used as the option value of the MRL. In this study, the mean value was used for the option value of the MRL.

From the governmental point of view, the option value of the MRL is the potential gain. By matching this value to the potential loss (the option value of the MEL), the risks associated with the sewer system can be reasonably distributed between the contracting parties. As previously indicated, the risk-neutral probability of the rise and fall was estimated by investigating the changes in the O&M liability imposed on the private entity. In this work, the initial value of the O&M liabilities was assumed to be the accumulated O&M expense in the moderate case; the initial value of the O&M liability can be more accurately estimated if comprehensive data, such as the overall condition of the entire system, the rehabilitation history, the surrounding soil conditions, and so on, are available. The rise rate (u), fall rate (d) and risk-neutral probability of the rise (q) were calculated, respectively, as follows:

$$d = \sqrt{\frac{V_d^2}{V_o^2}} = \sqrt{\frac{425}{118.9}} = 0.6 \qquad (2)$$

Table 2. MRL Results from Monte Carlo Simulation

Statistics	Value
Trials	10,000
Mean (US dollars)	24,973,147
Median (US dollars)	24,490,160
Standard deviation	16,604,661
Skewness	0.1837
Kurtosis	2.82

$$u = \sqrt{\frac{V_u^2}{V_o^2}} = \sqrt{\frac{287.8}{118.9}} = 1.56 \tag{3}$$

$$q = \frac{(1 + r_f) - d}{u - d} = 0.47 \tag{4}$$

where V_o = the value of the O&M liability in 2003 (the accumulated moderate O&M expenses discounted back to 2003 = 118.9); V_u^2 = the value of the O&M liability for the worst case in 2005 (the accumulated worst O&M expenses discounted back to 2005 = 287.8); V_d^2 = the value of the O&M liability for the best case in 2005 (the accumulated best O&M expenses discounted back to 2005 = 42.5); and r_f = the risk-free interest = 0.045.

As shown in Fig. 6, the MEL agreement was only exercised in the worst case. The option value of the MEL as of 2005 was computed using a forward calculation. Thus, by subtracting the 2005 year option value of MEL from the value of O&M liability as of 2005, the exercise price would be estimated and the value was $162.9 million.

In this study, the exercise value of the MEL was estimated by matching the option value of the MRL with that of the MEL. This concept can be applied to situations where the government is able to cover only a portion of the O&M expense due to a lack of available funds. In other words, if the exercise value of the MEL is fixed, the exercise value of the MRL can be estimated through a reverse procedure. For example, when the exercise value of the MEL was established as $220 million, the corresponding exercise value of the MRL was 27.7%. The overall procedure for the risk-sharing approach is illustrated in Fig. 7.

Impact of Key Variables on the Value of the MRL and the Exercise Value of the MEL

Sensitivity analyses were conducted to investigate the impact of the key variables on the value of the MRL and the exercise value of the MEL. The variables used in the Monte Carlo simulation to determine the value of the MRL were the initial sewer tariff, initial population, rate of population increase, and rate of sewer tariff increase. The sensitivity of the variables to the value of the MRL is shown in Fig. 8(a). The initial sewer rate and the initial population had the largest impact on the value of the MRL, with influences of 67.3% and 19.6%, respectively. Since the initial population can be reasonably estimated before the contract was established, the initial sewer tariff would be the key condition to be negotiated. The impact of the input variables on the exercise value of the MEL is shown in Fig. 8(b). The value of the MRL was used as the starting value in the binomial model. Thus, only the risk neutral probability positively affects the exercise value of the MEL, as shown in Fig. 8(b). It can be inferred that the value of the MRL and the exercise value of the MEL are negatively correlated. If the value of the MRL increases, the exercise value of the MEL decreases. This is understandable because a larger exercise value of the MEL means a smaller option value of the MEL.

Financial Impact of the MRL and MEL on the Government

From the governmental point of view, the MEL agreement represents the conditional liability that would be activated if a sizable

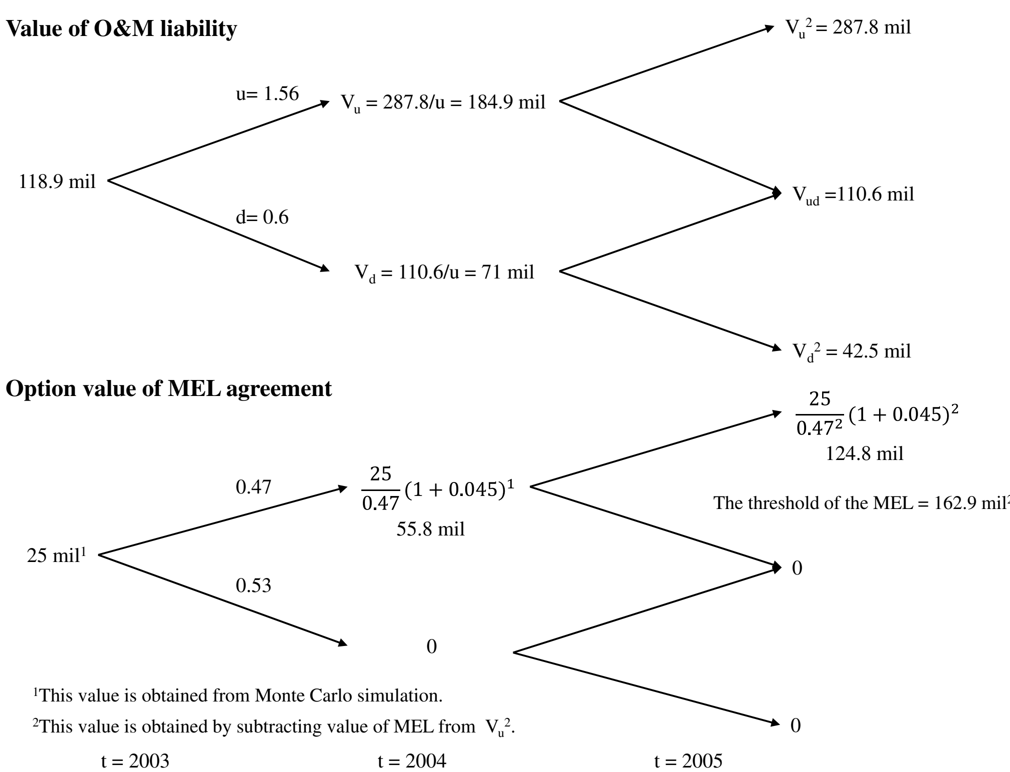

Fig. 6. Computation of the threshold value of the MEL

O&M expense was incurred beyond the expectations specified by the contract. In contrast, the MRL agreement signifies the potential gain to the government when the private entity's rate of return is much larger than the specified minimum attractive rate of return (MARR). These agreements should interact so as to mitigate the potential risk to both trading parties. In order to ensure equal sharing of the potential risk, the amount of expected gains should be equivalent to the amount of the expected loss. Such a concept could evolve into a proportional risk allocation model that is based on the negotiations and reflects the specific circumstances of the projects. In some cases, the private entity may be willing to accept a larger amount of risk if they are interested in entering into new markets or starting business with new clients. In other cases, governments can take additional risks when they need to attract the interest of more private entities. The model can easily be modified when subject to the actual circumstances of each unique sewer system.

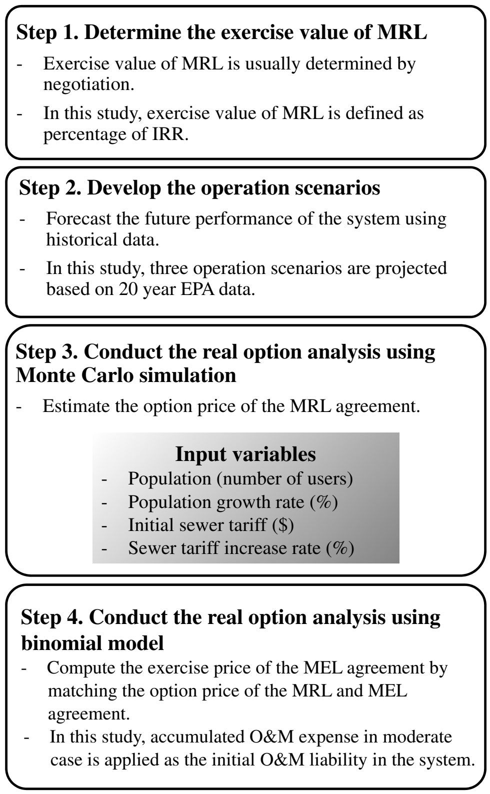

Fig. 7. Overall procedure of the risk-sharing approach

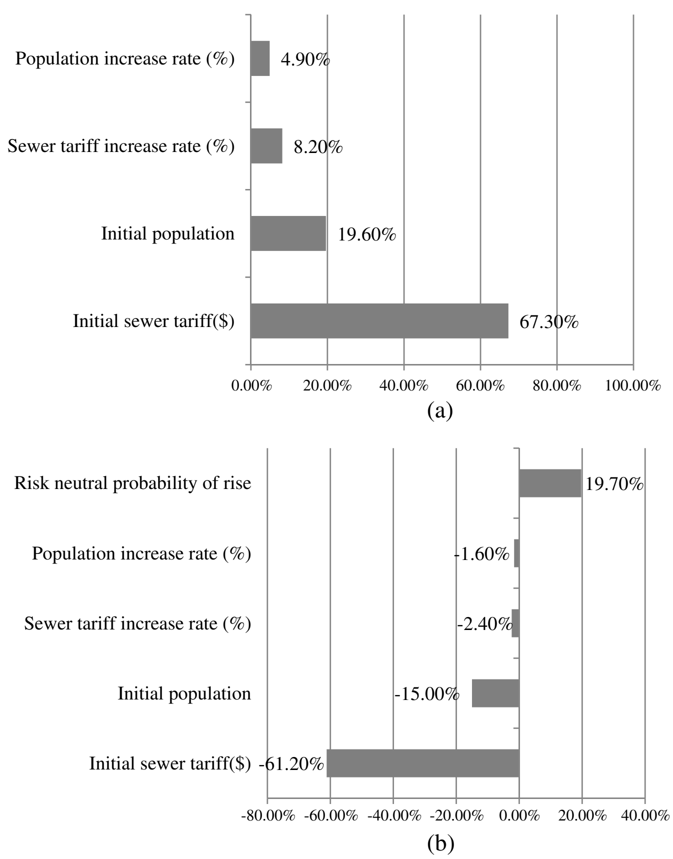

Fig. 8. Sensitivity analyses for the key variables: (a) option value of MRL; (b) exercise value of MEL

Contributions of the Study

The primary objective of this study was to propose a new contract model to realize sewer and water privatization with an emphasis on sound risk distribution. Through the combination of MRL and MEL agreements, the proposed contract model establishes a fair and reasonable framework to satisfy all of the interested parties. The contributions of the proposed model to the existing body of knowledge are threefold. First, the model is unique in the sense that it employs two call options. Unlike other existing approaches, the MRL and MEL are both call options. Such a feature is aptly suited to the unique characteristics of sewer system privatization. The model is also different from other schemes because it reflects the cost structure of revenue and expenses simultaneously. Second, the presented case study included a numerical projection of three different operation scenarios for a water and sewer system. It could be used as a benchmark for future privatization contracts because the values for the input were obtained from 20 years of historical data across the United States. Third, the sensitivity analyses showed the extent to which each key variable influences the value of the MRL and the exercise value of the MEL. The results of these analyses could be used as guidelines for determining contractual terms between the government and a private entity.

Conclusions

Recently, the privatization of water and sewer systems has become a trend in the United States due to the financial difficulties of the government. In some cases, however, the public have suffered rate hike and poor service and finally insisted on the renationalization of the system. Such a scenario arises mainly from the absence of a comprehensive understanding of the cost structure of the water and sewer system as well as contractual devices to hedge against the extreme outcomes that the system would encounter. In this study, a new contract model that can satisfy all related parties was presented. Included in the model were the concepts of the maximum revenue limit (MRL) and the maximum expense limit (MEL). The basic idea behind the utilization of the MRL and MEL was that the potential loss from the MEL should be systematically compensated by the potential gain from the MRL. A real option analysis was conducted so as to balance out the payoffs of the MEL and MRL. Thus, the potential cash outflow from the MEL is reasonably offset by the expected cash inflow from the MRL. A Monte Carlo simulation was employed to estimate the value of the MRL. This value was used as the starting value of the

MEL in the binomial model. Finally, the exercise value of the MEL was properly estimated.

The optional agreements used in this study increase the value of the project and further prevent a lopsided contract. In addition, since the MEL agreement can be beneficial to the private entity without sudden increase of the sewer rate, the public will likely be willing to accept the privatization of the system when this agreement is included in the contract. A case study of the privatization of the sewer system was conducted in order to investigate the impact of the MEL and MRL agreement on the value of the project. The case study emulated the 20 year operation data of sewer systems across the United States to demonstrate a practical application of the MEL and MRL. Using sensitivity analyses, the key variables that can be used in negotiation processes were identified. However, future study is required to clearly identify the impact of various market and project specific risks on the project values for further improvement of the proposed model.

This study applied a combined valuation structure of a Monte Carlo simulation and a binomial lattice model to bring a new cost structure (revenue and expense) into the sewer system contractual agreement. Consequently, a firm base from which contracting parties can properly evaluate the feasibility of upcoming PPP projects for water and sewer systems was established. The proposed model can further organize contractual agreements that lead to a win-win situation for all contracting parties and even the public.

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