Water Resour Manage (2010) 24:2881–2892
DOI 10.1007/s11269-010-9585-0

Real Options for Increasing Value in Industrial Water Infrastructure

Pongsak Suttinon · Seigo Nasu

Received: 9 December 2008 / Accepted: 8 January 2010 /
Published online: 21 January 2010

Abstract This paper presents a flexible approach that is real options to increase expected value in water infrastructure systems. Real options make an adaptable ability to respond the systems more effective to good opportunity and withdrawn unproductive situations from loss of investments in the future. The result of this approach is compared with traditional net present value in cases of with and without uncertainty to show expected values of investment of industrial water demand and supply schemes. It shows that real options in system can increase expected value of investment by reducing negative risks and increasing opportunities. An example of water infrastructure investment to support increasing industrial water demand demonstrates the use and results of this approach.

Keywords Real option · Flexibility · Uncertainty · Industrial water demand management

1 Introduction

Infrastructure investment is one of the important processes which governments have to make a decision to accept or reject projects under uncertainties in the future. A large majority of all infrastructure projects uses profit as the sole measure of

P. Suttinon (✉) · S. Nasu
Research Center for Social Management, Kochi University of Technology,
185 Miyanokuchi, Tosayamada-cho, Kami-city, Kochi, 782-8502, Japan
e-mail: pongsak.suttinon@kochi-tech.ac.jp

S. Nasu
e-mail: nasu.seigo@kochi-tech.ac.jp

acceptability (Jack and Samuel 1995). Decision makers always choose the optimal choice by using Discounted Cash Flow (DCF) such as Traditional Net Present Value (NPV) or Internal Rate of Return (IRR) as the profit test for project acceptance. The DCF method values the future profit over the project life into present time and evaluates it with choices of to construct or to do nothing at the initial time of analysis. The project is deemed acceptable or successful if the net present value is positive. These methods are easy to use and understand. From this advantage, DCF method was always selected for infrastructure development. However, the main disadvantage of DCF is this method does not value flexibility to respond uncertainties in the future.

Real Option Analysis (ROA) is a financial approach originally coined by Myers and Turnbull (1977) who defined that "real options are opportunities to purchase real assets on possibly favorable terms". Sick (1995) stated more detailed definition of real options as "the flexibility a manager has for making decisions about real assets. These decisions can involve adoption, abandonment, exchange of one asset for another or modification of the operating characteristics of an existing asset". An introduction of ROA was presented by Myers (1984), Dixit and Pindyck (1994), Trigeorgis (1996), Amram and Kulatilaka (1999), Copeland and Antilarov (2001), and Smit and Trigeorgis (2004). These findings suggest that this approach can embody flexibility in the project development. Real options are the right, but not the obligation to take actions in the future.

Since the early 2000s, ROA has been applied to the field of infrastructure system. Rose (1998), Leviakangas and Lahesmaa (2002), and Michael and Charles (2004) provide applications to toll road infrastructure projects. Ping and Liang (2002) demonstrate how ROA evaluates the financial viability of a privatized infrastructure project. Smit (2003) proposes using ROA to analyze expansion of the airport industry. Tong and Chung (2003) apply ROA to parking garages. De Neufville et al. (2006) suggest ROA by using spreadsheet to parking garages. Charles and Jicai (2006) show an application of ROA in the Malaysia–Singapore Second Crossing. Anastasios and Konstadinos (2007) describe the utility of ROA to irrigation dam investment analysis.

However, there is a little practice using ROA in water resources engineering field especially industrial water infrastructure development which is complex and challenging. There are many reasons. For example, ROA is a financial approach which needs understanding of financial theory. The data for analyzing is not accessible. It is difficult to understand for engineers or policy makers who always use discounted cash flow to evaluate the project development.

The objective of this paper is to identify the optimal method for evaluation of industrial water infrastructure development by comparing three methods as follow; (1) Traditional Net Present Value (NPV) which has been widely used for engineers, (2) NPV with uncertainty in the future, and (3) Real Options Analysis (ROA). The case study was selected from industrial water infrastructure development projects to support higher water demand from declared governmental strategies in the future. Comparisons of three approaches were analyzed in national and regional scale of Thailand. The forecasting period is divided in each 5 years from 2005 to 2025. The reason that forecasting starts from 2005 because of the most updated Thailand input–output table was declared by National Economic and Social Development Board in 2000 (Dec, 2008).

1.1 Definitions

1.1.1 Uncertainty and Risk

The Oxford English Dictionary (Simpson and Weiner 1991) defines "uncertainty" as "Lack of sureness about someone or something. Uncertainty may range a falling short of certainty to an almost complete lack of conviction or knowledge especially about an outcome or result." There are many sources of uncertainty in the future shown as follow; technology, economic and financial, regulations, industry, and political. Base on the general rule, forecasts are always wrong under these uncertainties.

1.1.2 Flexibility

According to Ku (1995), Flexibility means the ability to change by (quickly) moving to a different state, selecting a new alternative or switching to a different production level. Robustness on the other hand is associated with not needing change. While flexibility is a state of readiness, robustness is a state of being. Flexibility and robustness are not opposite or the same, but two sides of the same coin, two ways of responding to uncertainty.

2 Methodology

2.1 Industrial and Water Situation in Thailand

During the past 10 years, Industrial sector is also play an important role in Thai economic development with ratio of 40% of total Gross Domestic Product (GDP) (NESDB 2008). At the same time, GDP of manufacturing activities at constant 1988 prices was gradually developing with 6.7% growth rate per year (NESDB 2008). These rapid growing industrial units are showing increasing trend in water demands and development of new water infrastructures.

Water is one of the most precious natural resources and the lifeblood for sustained economic development in any country. Development in economic production needs more water not only in industrial sector but also in domestic, tourism, agriculture, etc. Water shortage is the critical problem of these water users especially in the dry season. One of the interesting cases was occurred in the eastern part of Thailand located by main industrial estates in 2005. Water was extremely shortage caused by low rainfall since 2004. Low water supply in reservoirs was not enough to support all water users. Industrial sector was mostly damaged from this shortage. The government has planned to construct big reservoirs reducing the threat of water shortage in the eastern part for the dry season. This situation forced Thai government to manage industrial water supply and demand integrated with socio-economic development and financial consideration.

2.2 Industrial Water Demand

Industrial water demand means water used to manufacture such as food, textile, chemical, etc. includes water used as utility process (boiler, cooling system), production (raw material, washing, etc.), and other uses in factory. Industrial water demand was analyzed and forecasted by using two main parameters (Suttinon 2008). The first one is economic value as industrial cost of production in monetary terms calculated by Input–Output (IO) table. This IO value is the main analysis of economic part shown in Fig. 1. The second is water use unit per value of production which needs water in processes.

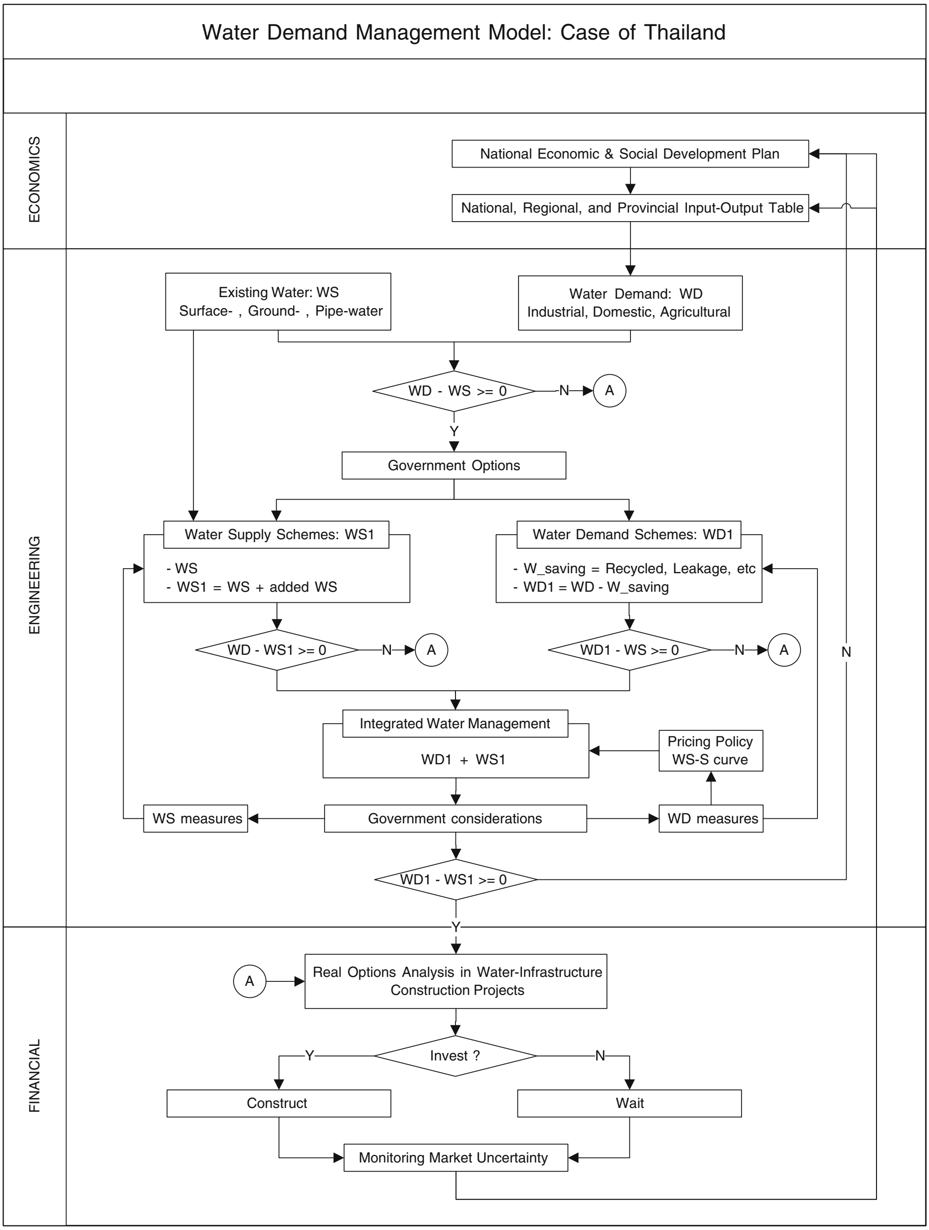

Fig. 1 Schematic diagram of water demand management model: case of Thailand

First, Value of production or total output showed in IO table is summation of industrial cost and value added. Industrial cost means value of real production which needs inputs such as raw material, water, etc. to produce outputs. Next, value added is the higher value of selling products from producers to customers or next producers which there is no production process between two groups. By this meaning, only industrial cost needs water in production process and this cost in the future will be the first variable to calculate industrial water demand.

Second, there are two steps to calculate water use unit in industrial sector. Firstly, water use unit per million Thai Baht (THB) in each industrial major group should be surveyed in the most updated year as base year. In this paper, questionnaire survey in 2006 by Kochi University of Technology (Suttinon 2008) was selected as base year of this analysis. Next, decreasing water use unit in the future was analyzed from cases of other countries.

2.3 Input–Output Table

The objective of this part is to generate the new IO tables with economic targets of Thai government. Input–Output (IO) table shows interrelationships among inputs and outputs of production cost, value added, and total output in agricultural, industrial and service sector. It is normally surveyed and published in only national scale by National Economic and Social Development Board (NESDB) of Thailand. There were two main steps to forecast the provincial IO table used in this paper. The first process was to generate the new national IO table from targeted GDP's growth rate in the future. This target was analyzed from national and international plans of Thai government. The second one was to transform the generated national IO table to provincial scale by using data of gross provincial products, industrial census, and the other conditions in that area. This transformed IO tables were used to calculate provincial water demand with the water use unit produced in the next step.

2.4 Water Use Unit Analysis and Industrial Water Demand

The objective of this step is to analyze and forecast water use unit per monetary term in each industry major group. Total industrial water use in year 2006 was selected as base year to calibrate the water unit; however, the details of water use pattern in each industry group were applied from case study of 7 provinces in Lower Chao Phraya River Basin (Suttinon 2008). The water use units per GDP in the future were not constant. They are decreasing in many countries such as the United States, China, Japan, etc. (Gleick 2002) The reasons are higher economic of water (less water use per monetary unit), water saving policy, less water technology, etc. Finally, industrial water demand in each major industry group shown in engineering part of Fig. 1 was forecasted from previous generated production cost and water use unit.

2.5 Assessment of Water Distribution and Demand Management Policy in Terms of Quantitative Benefits and Policy-making System

After industrial water forecasting process, water supply and demand equilibrium analysis was conducted. In case of water demand was more than supply, government has to make a decision to use water supply or demand measures to solve this water shortage problem. Water supply scheme is a form of increasing water quantity; for example, to build, enlarge, or repair water infrastructure. Water demand scheme concentrates in decreasing water use such as laws, pricing policy, recycled water, and the other ways. In this paper, combination of water supply and demand schemes was selected as to build more pipe water system, develop leakage reduction, and use recycled water.

The objective of this step was constructing an optimal water distribution and demand management policy-making system for provincial scale in Thailand. Total benefits can be attained when water supply and demand are in equilibrium in the respective sectors of environment, agriculture, industry, and domestic, under views of Thailand's agricultural and industrial cluster development policies, and water demand–supply schemes. An equilibrium point was obtained from a water price elasticity and cost function model of different water resources (groundwater, industrial water, recycled water, etc.). The effects of limited groundwater use and pricing policy will be modeled for analysis also. Finally, the model was constructed with the basic aim of maximizing provincial societal benefits, by making water distribution policy with a water demand equilibrium model that takes into account industrial policy, economic plans, water pricing policy, and other factors for water demand. However, if water demand is still less than water supply, it means that the economic target is not possible with water condition. Policy makers should reduce the target or consider the development plan again as shown in economics and engineering parts of Fig. 1.

2.6 Water Infrastructure Investment

In this process, infrastructure investment was arranged after total water demand for industrial, agricultural and domestic purposes was in equilibrium. The objective of this part was to evaluate industrial water infrastructure development project of the suitable water demand and supply measures. Figure 1 showed that after government has already considered using combination of water supply and demand measures, they need to make a decision whether and how water infrastructure should be invested under uncertainties in the future.

Because of uncertainties, if Thai economic condition is changed in the trend of demands volatility is increased; the range of the possible water demand will widen also. It is possible that water demand will exceeds capacity of constructed water infrastructure. From this reason, water shortage problem happens or increasing deficit cost. On the other hand, if water demand is low from economic crisis, Thailand has too much water to use or increasing opportunity costs.

If policy makers decide to use flexibility strategy instead of robustness approach, assume that they might construct a series of smaller reservoir with expansion process. Although the cost of these small projects is higher than one big reservoir from economies of scale, but their advantage is that they become more valuable when uncertainty increases. However, policy makers can decide options to construct the next project (if water demand is increasing) or stop its construction (if water demand is decreasing). It means that policy makers can monitor the uncertainty caused changing economic situation or national plan.

In the past, constructing big infrastructure is always selected because of economies of scale (in condition of without financial problem). Now the idea is changing. When the projects were evaluated with unstable and uncertain environment, the loss from the negative side of uncertainty or risk is expensive. Flexibility is one of the powerful tools to improve the value of infrastructure project.

In this paper, the optimal method for evaluation of industrial water infrastructure development was identified by comparing three methods as follow; (1) Traditional Net Present Value (NPV), (2) NPV with uncertainty in the future, and (3) Real Options Analysis (ROA).

2.7 Traditional Net Present Value (NPV)

Net Present Value (NPV) and Internal Rate of Return (IRR) are two common approaches of Discounted Cash Flows (DCF). The objective of NPV is to discount cash flows of future revenue and expenditure into present time. If NPV is positive or more than zero, it means that the project is worth more than its costs or there is profit from this project.

$$NPV = \sum_{t=0}^{T} \frac{R_t - E_t}{(1+r)^t} \tag{1}$$

Where, t is the time of the cash flow; T is total time of the project; Rt is revenue in time t; Et is expenditure in time t; and r is discount rate. In this paper, the total time of this project is until year 2025 which is the same year as the water demand management model. Revenue was calculated from unit price in each water source. Cost was calculated from combination of production, construction, and land leasing cost. Water price, cost and construction cost were collected from Metropolitan Waterworks Authority (MWA 2006). Water demand data was calculated from developed water demand management model shown in Fig. 1.

The difficulties of NPV method are how to define adequate discount rate and it is assumed to be constant over the project life. Discount rate reflects risk of project. It is translation factor of present and future money. The selected discount rate as 7.8 percent in this paper was calculated from the average value of central bank discount rate data in 1990 to 2006 by the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP).

2.8 NPV with Uncertainty

One of main disadvantages of traditional NPV is that it makes decision to go or stop under available information in the present time. It means that traditional NPV cannot account uncertainty in the future. However, NPV can calculate with uncertainty by using Monte Carlo simulation. The process is shown as follow; 1) to generate 200 sets of random demands in each time period, 2) to analyze numbers of NPV in term of statistic(such as mean, maximum, minimum value, and occurrence period), and 3) to generate distribution of NPV.

2.9 Real Options (RO)

Real Option Analysis was first developed in the financial society to response to inadequacy of NPV. It is the approach for analyzing complex system to identify uncertainty and create flexibility. Flexibility enables policy makers or decision makers to proactively manage the risk to achieve the strategic objectives with maximum system value.

RO enables policy makers to consider when is appropriate to construct or continue the system because it gives flexibility to defer choices with the suitable time of investment. From this reason, RO is most valuable with the condition of uncertainty in the future. It is appropriate to use RO with water infrastructure projects of large scale, long life of project, and high budget.

The process of estimating the value of real options in this paper was developed with simple way to understand and execute with source code in WATER DEMAND MANAGEMENT MODEL by KOCHI UNIVERSITY OF TECHNOLOGY or KUT-WDM-02 in case of Thailand. The process was shown as followed:

1. To input the forecasted changing industrial water demand by declared governmental scenarios with the selected measure from water demand and supply schemes.
   In this paper, the selected measure is to build more pipe water, to develop leakage reduction system and to use recycle water. The quantity and price of each water source was prepared to calculate cost and revenue of project.
2. To combine uncertainty by simulating possible random demands from Monte Carlo simulation.
   Each generated water demands produce each NPV. It means that the possible NPV were produced at the same time. In this step, statistical analysis such as average, maximum, and minimum NPV was applied as same as NPV with uncertainty.
3. To assign options scenarios to provide flexibility.
   In this paper, step of construction was defined as design alternative, for example, policy makers will consider building water supply system from the cheapest to the highest price or from pipe-water (0.41 \$/m^3; average price of all provinces under service area of MWA and PWA) to leakage reduction system (0.50 \$/m^3) to recycle water (0.60 \$/m^3) (Suttinon 2008). The comparison of value will be shown in form of Cumulative Distribution Function.

3 Results

Table 1 shows results of three methods; traditional net present value (NPV), NPV with uncertainty without options, and NPV with options. The results in all methods were calculated by using statistic analysis such as average, maximum, minimum expected value, option values, and occurrence chance in each percentage. In this paper, national (THA) and regional scale (Bangkok and Vicinity, BV; sub-central region, SC; etc.) were presented by using summation of calculated provincial results.

As can be seen in Table 1, it shows that only mean of NPV with options is positive and more than both cases of traditional NPV and NPV with uncertainty in all Thailand and regional levels. This is because policy can make a decision due to uncertainty in the future; for example, to build more infrastructures if the water demand increase from economic boom or stop the project from decreasing water demand from changed strategy of new governments. However, the model shows whether the projects should be invested in each approach.

Table 1 Results from each approach (unit, 10^6 \$)

Approach	Statistic analysis	Area							
		THA	BV	SC	EA	WE	NO	ST	NE
Traditional of net present value or NPV1		−66	−26	−10	−15	−2	−3	−2	−3
Net present value with uncertainty or NPV2	Mean	−69	−28	−11	−15	−2	−3	−2	−3
	Max	118	72	8	27	4	6	4	4
	Min	−306	−157	−36	−67	−11	−16	−11	−12
	5% chance NPV<	−269	−138	−32	−58	−9	−13	−10	−10
	10% chance NPV<	−247	−120	−28	−53	−8	−12	−8	−9
	5% chance NPV>	75	46	4	15	2	3	2	2
	10% chance NPV>	89	57	5	18	3	4	3	3
Real options or NPV3	Mean	301	165	32	62	10	15	11	12
	Max	412	216	42	84	13	20	15	16
	Min	218	121	24	45	7	11	8	9
	Option value	367	191	42	77	12	18	14	14
	5% chance NPV<	248	136	26	50	8	12	9	10
	10% chance NPV<	259	143	27	53	8	13	10	10
	5% chance NPV>	341	182	36	70	11	17	13	13
	10% chance NPV>	354	188	37	73	11	18	13	14

THA Thailand, *BV* Bangkok and vicinity, *SC* sub-central region, *EA* eastern region, *WE* western region, *NO* northern region, *ST* southern region, *NE* northern region, if 1 \$ = 33.38 THB

From the means of NPV in all cases, the project should not be invested in case of traditional NPV and NPV with uncertainty because of negative value or loss of investment. However, in case of NPV with uncertainty, the NPV values are varied from negative to positive. It means that the project is possible to invest with benefit or loss in the future. However, policy makers can make a decision with possibility of occurrence; for example, there is only 5 percentage of chance that NPV with uncertainty in Thailand will be more than 75 million US dollars.

On the other hand, positive means of NPV with options show that this project should be invested in all national and regional levels. Beyond the option value, the flexibility provided by building infrastructure with the lowest cost of water at the start and option to build the others with higher cost has several advantages. The comparison shows that expected NPV, minimum–maximum values, and value in each occurrence chance are better with options. It indicates that real option analysis reduces the maximum possible loss which is the value of risk.

Although the NPVs of traditional method and NPV with uncertainty are negative or loss from investment, policy makers can increase the value of project by using real options analysis and tend to have the benefit from investment.

The cumulative distribution functions (CDF) of net present value (NPV) for cases of with and without options are shown in Fig. 2. The CDF for NPV without options was calculated with uncertainty by using Monte Carlo simulation. In case of with options, NPV was analyzed by using same simulation with options scenarios of steps of construction. In this case the ”combination of water supply and demand schemes (new pipe water supply, leakage reduction, and recycle water) ” was selected and it was assumed that policy makers should consider building infrastructure from the cheapest to highest price.

As can be seen in Fig. 2, it shows that the expected values of NPV with options are more than case of without options. This is because policy makers made decisions

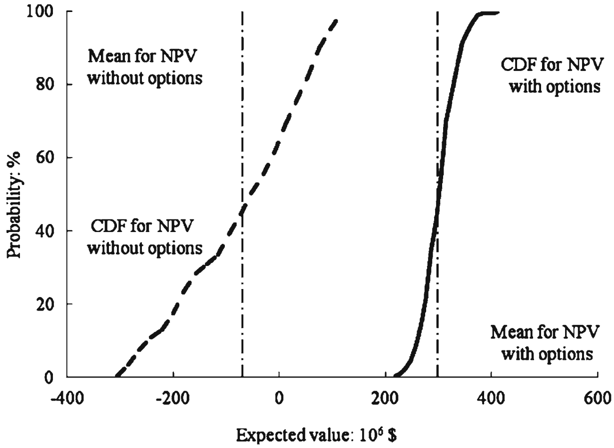

Fig. 2 Cumulative distribution function for NPV: case of with/without options in Thailand

to stop and continue the projects with the uncertainties of water demand in the future. In this model, policy makers decide to use flexibility strategy to construct water infrastructure (if water demand is increasing) or stop its construction (if water demand is decreasing). However, distribution of CDF in both cases cause by several factors of uncertainties in the future.

It seems that industrial water demand in Thailand changes from uncertainties such as economic (economic boom and crisis can both create new trends), regulations (groundwater ban law in Thailand with groundwater consuming factory such as textiles, food, and beverages), political (new industrial strategy from new government), etc. Both cases of with and without options face the same situations of uncertainties; however, investment with real options tends to increase the value of project of industrial water infrastructure.

Figure 3 shows the frequency of occurrence of NPV in case of with and without options. As can be seen in a comparison of the two lines, effect of real options is to

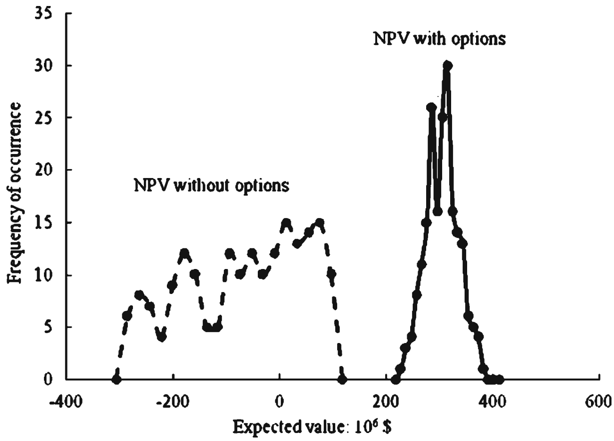

Fig. 3 Distribution of expected values for NPV: case of with/without options in Thailand

shift distribution of outcome to the right by reducing downside risks and increasing opportunities. The net effect is to increase the expected value.

4 Conclusion

Real options can increase expected value of water infrastructure investment comparing with traditional net present value in cases of with and without uncertainty. This is because real options make system flexible to make a decision in good opportunity and avoid loss from the risks in the future. It means that option value increases with greater uncertainty. This advantage meets the nature of water infrastructure that it involves long-term planning for uncertain projects. They are invested under water supply uncertainties such as unstable economic and political factors, and demand side from the needs of the users change. However, medium and small projects can use this approach with smaller option values. Real options analysis can provide a flexible framework that meets policy and decision maker needs within the water sector environment.

References

Amram M, Kulatilaka N (1999) Real options-managing strategic investment in an uncertain world. Harvard Business School, Boston

Anastasios M, Konstadinos M (2007) Using real options theory to irrigation dam investment analysis: an application of binomial option pricing model. Water Resour Manage 21(10):1717–1733

Charles C, Jicai L (2006) Valuing governmental support in infrastructure projects as real options using Monte Carlo simulation. J Constr Manag Economics 24(5):545–554

Copeland TE, Antilarov V (2001) Real options—a practitioner's guide. Texere, New York

De Neufville R, Scholtes S, Wang T (2006) Valuing real options by spreadsheet: parking garage case example. J Infrastruct Syst 12(2):107–111

Dixit AK, Pindyck RS (1994) Investment under uncertainty. Princeton University Press, Princeton

Gleick P (2002) The world's water: the biennial report on freshwater resources 2002–2003. Island, Washington, DC

Jack RM, Samuel JM (1995) Project management: a managerial approach. Wiley, New York

Ku A (1995) Modeling uncertainty in electricity capacity planning. Doctoral Dissertation, London Business School, London

Leviakangas P, Lahesmaa J (2002) Profitability evaluation of intelligent transport system investments. J Transp Eng 128(3):276–286

Metropolitan Waterworks Authority (MWA) (2006) The eighth Bangkok water supply improvement project, Thailand. Bangkok, Thailand

Michael JG, Charles YJC (2004) Valuation techniques for infrastructure investment decisions. J Constr Manag Economics 22(4):373–383

Myers S (1984) Finance theory and financial strategy. Interfaces, pp 71–79

Myers S, Turnbull SM (1977) Capital budgeting and the capital asset pricing model: good news and bad news. J Finance 32(2):321–333

Office of the National Economic and Social Development Board or NESDB (2008) National income of Thailand, 2008 edn. Bangkok, Thailand

Ping SH, Liang YL (2002) An option pricing-based model for evaluating the financial viability of privatized infrastructure projects. Constr Manag Econ 20:143–156

Rose S (1998) Valuation of interacting real options in a toll road infrastructure project. Q Rev Econ Finance III, Issues in Application, Special Issue, 1998

Sick G (1995) Real options. In: Jarrow RA, Maksimovic V, Ziemba WT (eds) Handbook in operations research and management science-finance, vol 9. Elsevier, Amsterdam, pp 631–691

Simpson J, Weiner E (1991) The Oxford English dictionary, reprinted (with corrections), 2nd edn. Clarendon, Oxford

Smit HTJ (2003) Infrastructure investment as a real options game: the case of European Airport Expansion. Financ Manag 32(4):27–57

Smit HTJ, Trigeorgis L (2004) Strategic investment: real options and games. Princeton University Press, Princeton

Suttinon P (2008) Water demand management model in the Lower Chao Phraya River Basin, Thailand. Doctoral Dissertation, Kochi University of Technology, Kochi

Tong Z, Chung LT (2003) Valuing flexibility in infrastructure expansion. J Infrastruct Syst 9(3):89–97

Trigeorgis L (1996) Real options-managerial flexibility and strategy in resource allocation, 4th edn. MIT, Cambridge