APPLYING REAL OPTION APPROACH FOR EVALUATION OF AN EXPRESSWAY PROJECT IN JAPAN

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Abstract

Conventional Cost-Benefit Analysis cannot be used to include the uncertainties and options in management in the evaluation process. Therefore, this study develops a framework to incorporate uncertainties and options in management in economic evaluation for an expressway project, using a Real Option Approach concept. Techniques for modeling uncertainties in future traffic demands and construction costs are described. An option to defer toll collection in expressway projects is explained, and a calculation procedure employing the simulation technique is proposed. The Yoichi-Otaru expressway project in Japan is used in this study to demonstrate the procedure of the proposed technique. Various evaluation techniques are used to assess the project. The results showed that the project decision is affected when uncertainties in future variables and an option to defer toll collection are introduced. Deferral of toll collection has a relatively small effect on the total amount of revenue. The option to defer toll collection is most suitable when used in the beginning of the project. However, the managers must determine the actual number of years that the project should be operated with no toll after the actual construction costs are revealed and the actual traffic demands are observed.

Keywords: Economic evaluation; Expressway Projects; Real option approach;
Uncertainties; Option to defer toll collection
Topic Area: E1 Assessment and Appraisal Methods

1. Introduction

In the last few decades, Cost-Benefit Analysis (CBA) has been accepted worldwide as a standard tool for economic evaluation in expressway projects. The indices resulting from the CBA, such as Net Present Value (NPV), Benefit-Cost ratio (B/C), etc., are used to judge whether or not the projects are economical. This is done based on the assumption that all forecasting data used in the benefit and cost estimation will occur in the future. Unfortunately, it is usually found that the actual data is different from what is expected due to uncertainties in the forecasting variables. The project, economically evaluated by CBA, can be an uneconomical project if the construction cost is much higher than the expected cost. Thus, using CBA without considering uncertainties in the forecasting variables does not provide enough information in the economic evaluation for expressway projects.

In reality, active managers usually have strategic plans for managing the expressway project. The strategies are usually attempted to increase benefits while limiting losses on the project resulting from some unexpected variables. Managers can expand the capacities of the expressway if the future traffic demand is much larger than the expected demand. On the other hand, some policies should be made to limit loss if the actual traffic demand is much lower than expected. Thus, the options in management used to respond to unexpected situations due to uncertainties should be included in the economic evaluation process. Unluckily, managers cannot use CBA to model the management options in the economic evaluation process.

With the shortcomings in CBA, which cannot include the uncertainties and options in management in the evaluation process, an alternative approach is, therefore, required. The Real Option Approach (ROA), initially developed in the field of financing, can be employed to solve the problems, since it can incorporate uncertainties and management options in the evaluation process by extending the use of CBA principles. Thus, the ROA is able to provide a more accurate and complete analysis.

While the ROA is being applied in various fields, few studies have focused on expressway project evaluations. This paper, therefore, introduces a framework to adopt the ROA as an alternative economic evaluation process for expressway projects. Techniques to model uncertainties in benefit and cost estimations are described. A policy to limit loss in social benefits due to the uncertainties is also explained. Finally, the calculation procedures are explained. As a result, economic evaluations for expressway projects can be assessed, using the proposed framework.

To illustrate the framework, the Yoichi-Otaru expressway project in Hokkaido, Japan has been used as a case study. The project is evaluated by using various techniques. Then, the results of each technique are discussed and compared with the results from the ROA technique. Finally, recommendations for the project are proposed based on the proposed framework.

2. Real option approach (ROA)

The Real Option Approach (ROA) is a systematic and integrated decision analysis process used to evaluate investment projects, which are likely to be susceptible to uncertainties. It is the technique that extends from the financial option theory, which has been used in the stock market, to apply in real investments. Various types of options are proposed and analyzed by Dixit and Pindyck (1994), and Trigeorgis (2002).

The Real Option Approach (ROA) is developed from option pricing in the stock market. The option pricing theory enables the option owner to gain benefits from upside potential of an opportunity while controlling the downside risks. The definition of ROA given by Copeland and Antikarov (2001), is as follows: an option is the right, but not obligation, to take an action (e.g. deferring, expanding, contracting, abandoning, etc.) at a predetermined cost (exercise cost), for a predetermined period of time (the life of an option). The ROA, therefore, allows the decision makers to benefit from possible upside value while limiting future downside losses.

3. Real option approach for evaluation of expressway projects

Nowadays cost benefit analysis (CBA) is used as the evaluation tool to measure the economic efficiency of an expressway project in many countries (Hayashi and Morisugi, 2000). The CBA is still being applied in expressway project appraisal in Japan (Morisugi, 2000), United States (Lee, 2000), and many countries in Europe (Hayashi and Morisugi, 2000). The CBA process is based on the estimation of annual benefits that can be gained from the whole project life compared with the total project costs. Then, the discount cash flow method is used to account for the time value of money by discounting future values with a social discount rate to calculate the value in the base year. The results of the analysis provide some indices such as Net Present Value (NPV), Benefit Cost Ratio (B/C), etc., that inform decision makers about the economic efficiency of the project. Projects that are economically qualified, then, can be listed as candidates for implementation.

The CBA is normally used to evaluate the economic feasibility of an expressway project. Unfortunately, the CBA has many limitations. The uncertainties in future variables cannot be modeled in the CBA. Moreover, CBA cannot be used to measure the advantage of options in management to either enhance the opportunities to make more benefits or limit losses due to many risks.

Meanwhile, the Real Option Approach has been accepted as an evaluation process for projects under uncertainties in various fields. McCormack and Sick (2001) adopted the ROA for valuing undeveloped reserves in the oil and gas industry. Land development in Tokyo has been analyzed using the ROA by Yamagushi, Takezawa and Sumita (2000). Moel and Tufano (2001) used the ROA to identify the opening and closing time for gold mines in North America. However, applications of the ROA are still limited in the transportation field. Brand, et. al. (2000) introduced ROA in the process of risk analysis in transportation planning while Concas, et. al. (2003) used the ROA to value a transportation research and development project (TR&D).

In order to construct a framework to adopt the Real Option Approach to evaluating cost and benefit of an expressway project, uncertainties and options in management must be clarified. Then, a calculation procedure based on the simulation method is explained.

3.1. Uncertainties in expressway projects

Since an expressway project is a large-scale project with a long life cycle (30-40 years), it is normal to expect that the project would face various kinds of uncertainties both in benefit and cost estimation. While every parameter is subjected to uncertainty, however, it is recommended to consider only a few crucial variables (Savvides, 1994). This is because the greater the number of uncertainty parameters to be included in the analysis, the higher the likelihood that inconsistent scenarios will be generated in the calculation procedure. Moreover, it is likely to gain little in accuracy while requiring a greater effort. Thus, only the main parameters are considered to have uncertainty in the estimation of benefits and costs.

3.1.1 Modeling uncertainty in traffic demand

In the benefit estimation, a change in forecast for levels of traffic demand can yield dramatically different results in the benefit estimation. This is because traffic demand is a major input in all types of benefits resulting from the development of expressway projects. Thus, the uncertainty in forecasting traffic demand in expressway must be selected to be included in the analysis.

It can be seen from historical data that the total yearly traffic demand fluctuates greatly due to various reasons. The main reason comes from the strong relationship between yearly traffic demand and the national economic situation of that year. While uncertainties in the national economic situation can be modeled using some stochastic processes, yearly traffic demand can also be modeled using the same process. Thus, the annual growth rate for yearly traffic demand is predicted by using Geometric Brownian Motion (GBM) with drift rate as shown in [1].

$$\frac{\Delta Q}{Q} = \mu \Delta t + \sigma \varepsilon_t \sqrt{\Delta t} \qquad [1]$$

where, Q : yearly traffic demand
μ : constant annual growth rate for yearly traffic demand
σ : standard deviation of annual growth rate for yearly traffic demand
ε_t : normal distributed random variable N(0,1)

Dixit and Pindyck (1994) stated that "the GBM is an important stochastic process for modeling in the economic and finance fields. A stochastic process is a vairable that evolves over time in a way that is at least in part random. GBM has three important properties. First, the process is a Markov process, in which forecasting values depend only on current value. Second, the process has independent increments, which means that the probability distribution for the change in the process over any time interval is independent from other time intervals. Third, changes in the process over any finite interval of time are normally distributed, with a variance that increases linearly with the time interval".

It can be seen from GBM [1] that it consists of two terms. The first term is the constant annual growth rate for yearly traffic demand. It is constant because the average trend usually increases in the long run. However, the annual traffic demand doesnot increase steadily in reality due to many factors, such as the economic situation, etc. Thus, there is considerable uncertainty in the annual growth rate modeled in the second term of the GBM. By analyzing the historical data of traffic demand, it can be assumed that the effects of economic situations are already included in the standard deviation of annual growth rate. Thus, the future traffic demand can be modeled either upwards or downwards using GBM.

3.1.2 Modeling uncertainty in construction cost

In terms of the expressway project cost, it can be classified into two components, the investment cost, and the operating and maintenance cost (O&M). The investment cost can be broken down into the construction cost, land cost, and compensation cost. Operating costs of toll-collection, administration, and maintenance of expressway facilities during the service life of the project are the components of the O&M cost (Study Group on Road Investment Evaluation, 2000).

For expressway projects, construction cost plays a major role in the cost estimation. Moreover, the construction cost usually faces various kinds of uncertainties such as changes in design, lack of construction materials, unexpected technical problems, and so on. Therefore, the actual construction cost of large transport projects are usually found to be underestimated. Skamris and Flyvbjerg (1997) found that cost overruns of 50 to 100 percent above the estimated expense are found to be common in large infrastructure projects. Therefore, it is crucial to include uncertainty in construction cost in the evaluation process.

To model uncertainty in construction cost, some probability distributions for cost overrun are required. Triangle distribution, which is frequently used in risk analysis, is assumed for percent of construction cost overrrun. This is done by observing the range of minimum (a), most likely (b) and maximum (c) possible percentages of cost overrun as shown in Figure 1. The reason why b equals to zero is because the estimated construction cost is still believed to be the cost with the highest probability of actually occuring. Thus, triangle distribution which has its highest probability at zero can be used to model the uncertainty in construction costs. Based on the study by Skamris and Flyvbjerg (1997), the distribution in cost overrun is expected to be unsymmetrical. However, it should be noted that the degree of asymmetry should be varied from project to project due to difference in risks.

3.2 Option to defer toll collection

By recognizing that there are existing uncertainties in both forecasting traffic demand and estimating costs, active decision makers usually have strategic plans to react properly to the difficulty resulting from such uncertainties. Thus, actions that decision makers use to react to different situations due to uncertainties are called options in management or options. Although there are many kinds of options that managers can use, an option to defer toll collection will be examined in this study.

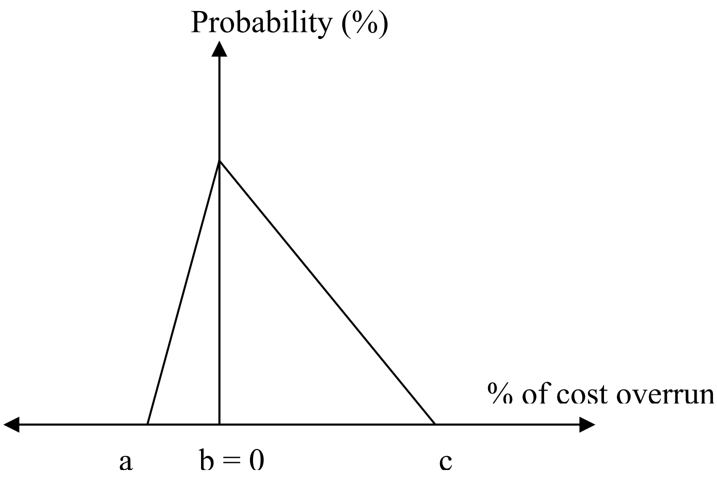

Figure 1. Probability distribution of construction cost overrun.

For the Japanese government, the policy for constructing expressways is to provide high quality road service as an alternative for road users, even though a toll is required for financing expressway development (Fujii, 1999). Meanwhile, the expressway project must be economical (social benefit more than cost) in the viewpoint of public. Thus, the framework of considering the option to defer toll collection is not merely to maximize social benefit. It must be considered in combination with need for revenue collection, while ensuring that social benefits are higher than costs.

The expressway project is considered worse than expected when uncertainties are continually revealed. After the construction is finished, the actual construction cost may be higher than the expected cost. Managers can observe that the traffic volume in the project is lower than the predicted volume when the expressway has operated for a while. The project that is evaluated as economical in the plannning stage could turn out to be uneconomical in reality. From the viewpoint of the government, managers have an option to defer toll collection for some periods in order to attract more users. By gaining more traffic demand on the expressway, the project has higher real chances to perform economically.

The increase in benefits resulting from the option to defer toll collection can be better described by using Figure 2. The social benefit is assumed to increase through time due to higher traffic demand in the future, which in turn results in higher benefit. When the main objective is to maximize the social benefit, the expressway should have no toll. However, a toll is charged to expressway users if the concept of a toll road (a policy of the Japanese government) is applied for the project. It can be expected that the traffic volume in the expressway in a case of no toll will be higher than in a case of charging a toll. Thus, the social benefit from the project will be lower when the expressway is a toll road. The benefit from the option to defer toll collection is the result from a combination of the two policies: attempting to get revenue from toll collection, while at the same time, ensuring that the project is economical. As a result, the increase in benefit resulting from option to defer toll collection of an expressway is a difference in the social benefit between the case of no toll and a case of charging a toll in the period that the option is used.

For example, an expressway project, which is economically evaluated in the planning stage, faces downside uncertainties (higher construction costs or lower traffic volume in the project), which cause the project to become uneconomical in reality. However, the project should be economical based on the viewpoint of the public. Thus, managers have the right to defer toll collection in the project until year x, where the increase in benefit could make the project economical. Knowing that the managers have the right to defer toll collection exists in reality, the option to defer toll collection should be included in the economic evaluation process.

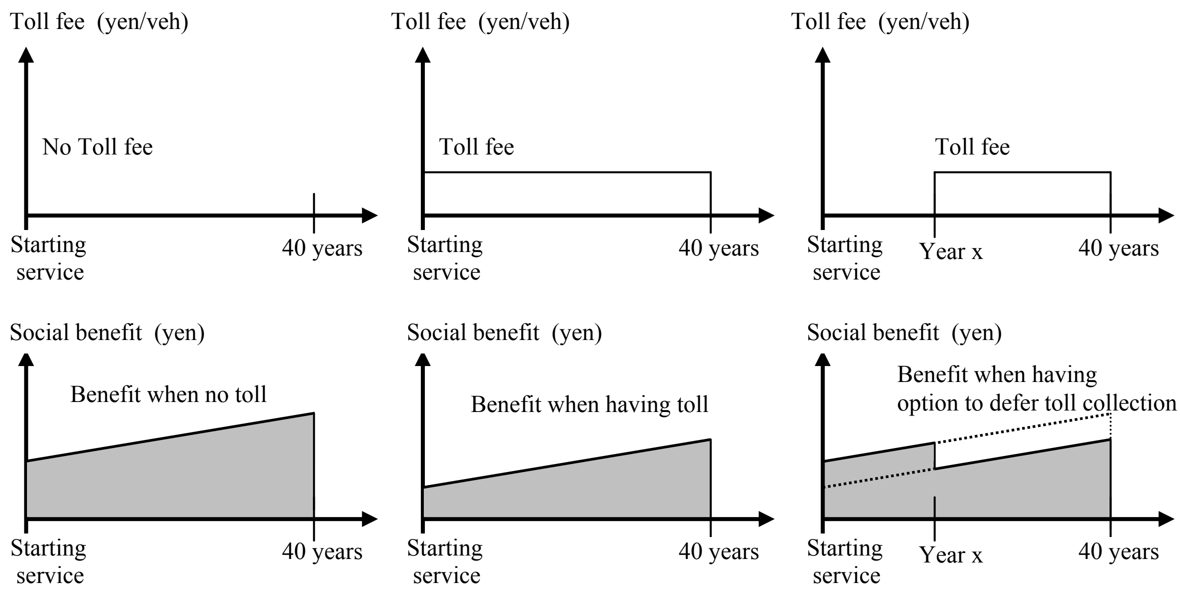

Figure 2. Increasing in benefit from the option to defer toll collection [Figure 2.]

3.3 Calculation procedure

It is known that even project planners are often concerned about uncertainties about the projects. However, they do not want to consider possible problems in practice due to the complexity in calculation and consumption of time (Mehndiratta, et.el., 2000). Therefore, a model that can deal with uncertainty without difficulty should be introduced to practitioners. The Black-Scholes model, which were proposed by Black and Scholes (1973), is a very popular model in option pricing theory. Unfortunately, it can be used only for European options (an option which can be exercised only at maturity), while in reality the option can be exercised anytime before maturity (American option). The partial differential equation technique is used by Dixit and Pindyck (1994), McDonald and Siegel (1986) in the Real Option Approach. However, the technique is considered to be difficult to implement in practice due to complexity in advanced mathematics. Binomial option pricing is used by Cox, Ross and Rubinstein (1979), Copeland and Anitkarov (2001), Concas, et.el. (2003). It is found to be efficient in calculation and less complex. Nevertheless, the binomial model has too many nodes when there is a long project life, which presents difficulty in compilation of data and in interpretation. It is also difficult to track the pace of the project in the binomial model, and know whether it is now in good or bad condition in the binomial tree. Among other techniques, the simulation method is found to be more effective than other techniques (Vose, 2000) to deal with real option because it can deal with many sources of uncertainties. Thus, the calculation framework in this study is based on the simulation technique. The calculation procedure by employing the simulation technique is shown in Figure 3.

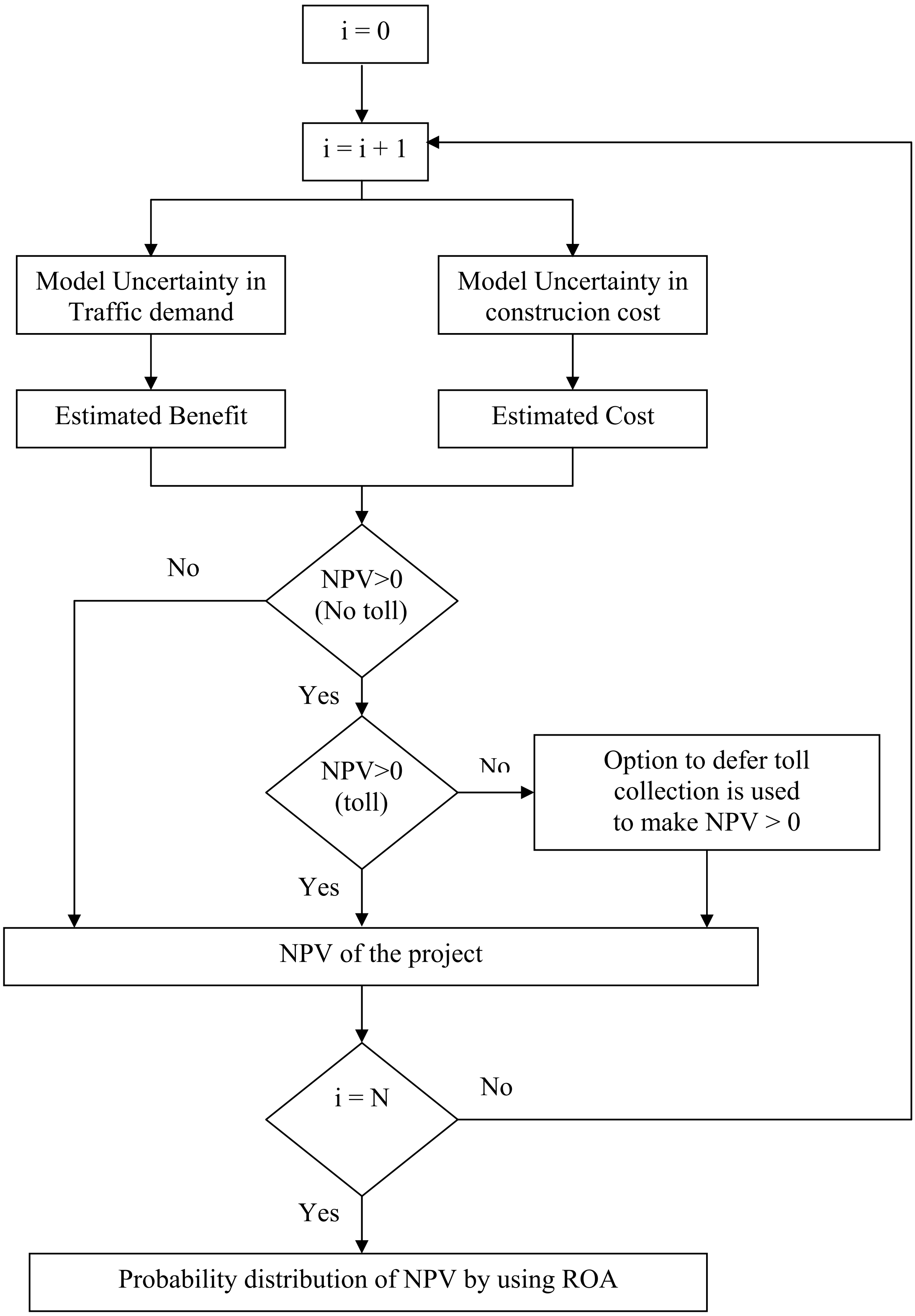

Figure 3. Calculation Procedure in ROA using simulation technique [Figure 3.]

The calculation procedure in the simulation process is usually based on repeated calculation of the Cost-Benefit Analysis. It starts with the modeling of uncertainties in predicted traffic demand and construction cost. Then, the estimated benefit and cost is determined. For the case that the project is already economical when toll has been collected since starting service, there is nothing to gain from the option. Again, if the project has a severe loss (even no toll for whole project life), the option is not helpful. The option to defer toll collection will be used when it is expected to be uneconomical when a toll is collected. Thus, benefits from using the option to defer toll collection can increase the fiscal viability of the project, but only by a certain amount.

4. Case study

To illustrate the proposed technique, which can include the Real Option Approach concept in an economic evaluation for an expressway project, a case study of an expressway project in Japan is evaluated.

4.1 Overview of the case study

The current plan for an expressway network in Hokkaido was proposed in 1987. However, the network has not been completed yet. The proposed expressway connecting Yoichi town and Otaru city, as shown in Figure 4., is currently still in the decision-making stage.

The planned expressway project will be a two-lane divided road with toll collection. The total length of the expressway will be 24 kilometers. The average daily traffic (ADT) of the parallel national highway is expected to be 16,000 vehicles per day (vpd). By considering uncertainty in forecasting traffic demand and construction cost, the projects can be used to demonstrate the proposed technique, applying Real Option Approach in the economic evaluation process.

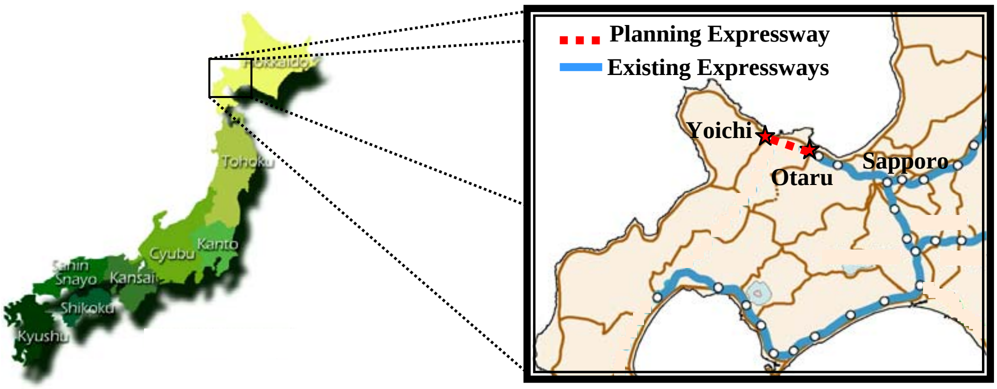

Figure 4. Location of the Yoichi-Otaru expressway project.

4.2 Modeling uncertainty in future traffic demand

The annual growth rate for traffic demand is estimated by using an Origin Destination (OD) table in year 1999 and the estimated one in the year 2020. A total of 16,174 passenger cars and 2,417 trucks is the traffic volume that used to travel on the road between Yoichi and Otaru in 1999, while the traffic demand is expected to increase to 23,991 for passenger cars and 3,011 for trucks in year 2020. As a result, the annual growth rate for traffic demand for passenger cars and trucks used in the GBM model is estimated to be 1.9 % and 1.05 % for passenger car and truck, respectively. After the year 2020, it is assumed that the traffic demand will be constant.

A standard deviation of the annual growth rate for traffic demand of 10.9 % is calculated by using historical data (1974-1999) of traffic volume along the national road number 5 from Yoichi to Otaru as shown in Figure 5(a). The annual growth rate for traffic demand was also tested to determine whether it has a normal distribution, using chi-square test. By performing the test with historical data of annual growth rates of traffic volume as shown in Figure 5(b)., the result shows that it can be modeled as a normal distribution ($\chi^2 = 9.75$, $\chi^2_{5,.05} = 11.07$).

It is known that there are a constant growth term and a standard deviation of growth rate term in the GBM model. In the simulation, the future traffic demand can be generated by calculating the inverse function of normal distribution in the normal distributed random variable parameter. Thus, it can be seen that the annual growth rate for each year is not the same. As a result, the generated future traffic demand can be predicted by using GBM.

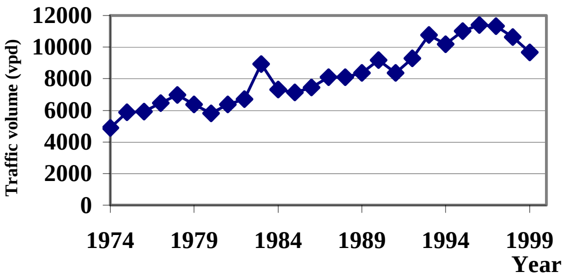

Figure 5(a). Traffic volume in Yoichi-Otaru highway

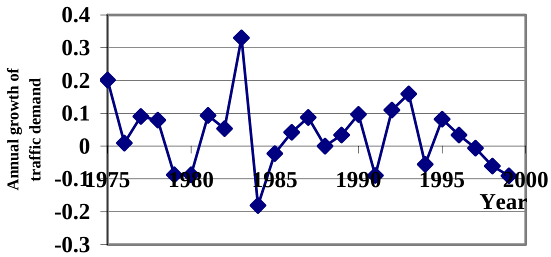

Figure 5(b). Annual growth rate of traffic volume in Yoichi-Otaru highway

4.3 Modeling uncertainty in construction cost

In cost estimation, the construction cost is estimated to be 120 billion yen while operating and maintenance cost is expected to be 1.35 billion yen per year. For uncertainty in construction cost, the percentage of cost overrun is assumed to follow triangle distribution T (-10, 0, 50). This means that the minimum of the cost overrun percentage is minus ten percent, which implies that the actual cost is lower than the expected cost. The estimated construction cost is expected to be the value most likely to occur. Cost overrun of 50 % is the maximum percentage that the construction cost might run over expected costs.

By generating a cumulative probability using a random number between zero and one, the value of percent cost overrun can be determined using the inverse function of a cumulative distribution function of the triangle distribution. Thus, the percent of cost overrun can be modeled and used in the simulation process.

4.4 Option to defer toll collection

Since the expressway project is an intercity expressway, the assignment of traffic demands for the expressway and parallel road are determined by using the diversion rate. This is done based on the assumption that the traffic demand is fixed in the demand estimation process. Thus, the diversion formula from Japan Highway Public Corporation

(JH) is used to determine the diversion rate of traffic demand that will be diverted from the national highway to the expressway, which can be shown in [2].

$$P = \frac{K}{1 + \left[\alpha(\frac{C/T}{S})^{\beta}\right] / T^{\gamma}} \qquad [2]$$

where, P : Percentage of diverted vehicles from parallel road to use the expressway
K,S : Parameters according to vehicle type
α,β,γ : Parameters according to vehicle type
C : Toll fee for using the expressway
T : Time saved when using the expressway compared with parallel road

In each iteration of the simulation, the option to defer toll collection can be exercised only when there is a loss in social benefit occurring in the project (the toll has been collected since opening the service). However, if the estimated cost is higher than the social benefit occurred in the case that a toll is not collected, the option to defer toll collection is not used. Thus, the distribution of NPV, when the project considers both uncertainties in future variables and the option to defer toll collection, can be identified.

4.5 Assumptions in cost-benefit analysis

As the calculation framework for the ROA using simulations basically relies on Cost-Benefit Analysis, all basis assumptions used in the Cost-Benefit Analysis have to be defined, which is shown in Table 1.

Table 1. Basic assumption for Cost Benefit analysis

Base year	year 2002
Social discount rate	4 %
Project life	40 years
Construction period	5 years

Various benefits usually occur when the new expressway is implemented. However, only benefits that can be converted into monetary terms are used in the economic evaluation process. Thus, the estimated benefits consist of saving in travel time, saving in vehicle operating cost, and a reduction in accidents, while the project costs are composed of the construction cost and operating and maintenance cost.

4.6 Economic evaluation results

Various techniques are available in economic evalaution for an expressway project. Thus, the Yoichi-Otaru expressway project is evaluated by using various evaluation approaches. The following approaches are used to assess the projects.

1. Cost-Benefit Analysis (CBA)
2. CBA with sensitivity analysis
3. CBA using simulation
4. CBA with an option to defer toll collection
5. Real Option Approach (ROA) (Considering both uncertainties and an option to defer toll collection)

4.6.1 Cost-benefit analysis (CBA)

The total benefit is estimated to be 118.8 billion yen while the total cost is 134 billion yen. Thus, the net present value (NPV) is expected to be negative: –15.2 billion yen, for the Yoichi-Otaru expressway project. The revenue, which comes from toll collection, is estimated to be 37.3 billion yen.

4.6.2 CBA with sensitivity analysis

By assuming that the forecasted value may be different from the expected value in the evaluation process, sensitivity analysis is sometimes recommended. The results of sensitivity analysis tell the decision makers what will happen if the predicted value is different from the expected value. This study sets up 6 cases for the sensitivity analysis.

case 1. Construction cost is 50 % higher than expected value
case 2. Construction cost is 10 % lower than expected value
case 3. Annual traffic demand growth rate is 10 % greater than expected value
case 4. Annual traffic demand growth rate is 20 % greater than expected value
case 5. Annual traffic demand growth rate is 10 % lower than expected value
case 6. Annual traffic demand growth rate is 20 % lower than expected value

The results of NPV when estimated future values are different from the expected values in both future traffic demand and construction cost can be summarized in Table 2.

Table 2. NPV of the project using CBA with sensitivity analysis

NPV (in billion yen)		Uncertainty in construction cost		
		50 % higher	No uncertainty	10 % lower
Uncertainty in traffic demand	20 % greater	-38.1	8.6	28.6
	10 % greater	-50.0	-3.3	16.7
	No uncertainty	-61.9	-15.2	4.8
	10 % lower	-73.8	-27.1	-7.1
	20 % lower	-85.7	-39.0	-19.0

4.6.3 CBA using simulation

By using the simulation to consider uncertainties in both future traffic demand and construction cost, the simulation is run for enough repeated computations (5000 runs in this study). The distribution of project revenue and NPV can be shown in Figure 6 and Figure 7, respectively.

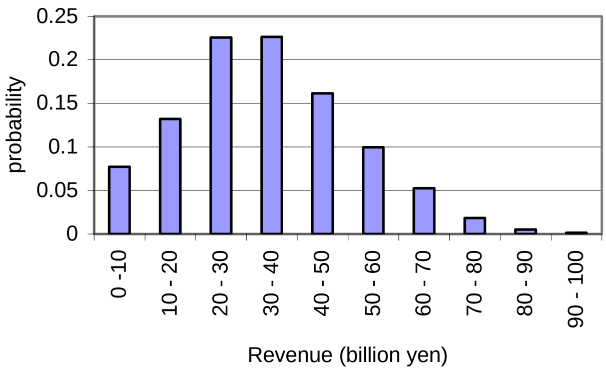

Figure 6. Distribution of revenue from CBA using simulation

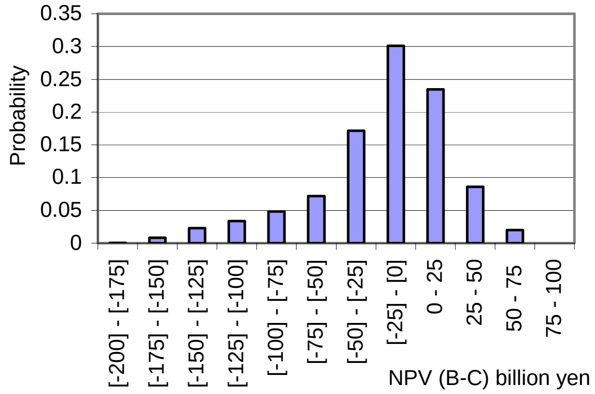

Figure 7. Distribution of NPV from CBA using simulation

From the distribution of revenue, the average of revenue is 34.1 billion yen with standard deviation of 16.9 billion yen. For distribution of NPV, the average value of project NPV is estimated to be minus twenty billion yen with a standard deviation of 42.9 billion yen.

When there are uncertainties in traffic demand and construction cost, the distribution of project NPV can show how much probability that the project will be economical, which is 34.1 % in this case.

4.6.4 CBA with an option to defer toll collection

The option to defer toll collection is calculated using CBA where no uncertainties are considered. The expected revenue is 32.2 billion yen. Since the project is uneconomical if the toll has been collected since starting the service, the results show that toll collection should be deferred for 1 year in order to make the project become economical (NPV = 0).

4.6.5 Real option approach (ROA)

By using the proposed calculation framework, 5000 simulations are run in this study. The distribution of project revenue and NPV can be shown in Figure 8 and Figure 9, respectively.

From the distribution of revenue, the average revenue is 29.9 billion yen with a standard deviation of 20.3 billion yen. For distribution of NPV, the average value of project NPV is estimated to be negative: –8.4 billion yen, with a standard deviation of 41.9 billion yen.

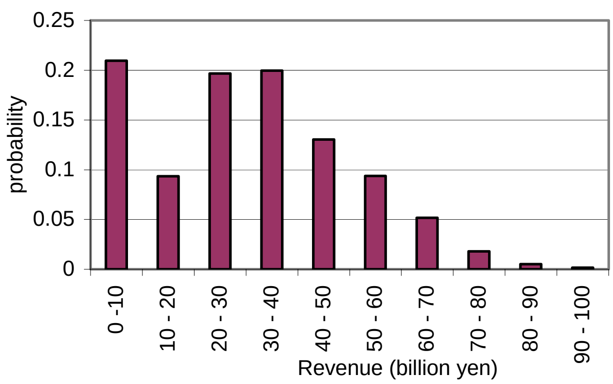

Figure 8. Distribution of revenue from ROA

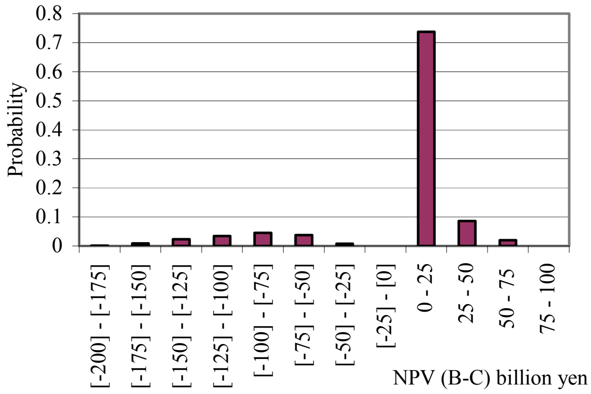

Figure 9. Distribution of NPV from ROA

When uncertainties in traffic demand and construction cost and the option to defer toll collection are included in the evaluation process, the distribution of project NPV can determine the probability that the project will be economical, which is 84.4 %.

4.7 Discussions of the results

To explore the effects of uncertainties of traffic demand and construction costs, and the option to defer toll collection, the results of an economic evaluation of the Yoichi-Otaru expressway project from various evaluation approaches are described. The results from five approaches are categorized into 4 groups based on the consideration of uncertainties and the option to defer toll collection.

4.7.1 Considering neither uncertainties nor the option to delay toll collection

If the project is evaluated by using CBA, the project should be abandoned due to the negative NPV (-15.2 billion yen). The CBA is not considering either uncertainties or the option to defer toll collections. This is hardly expected to occur in reality, when the predicted traffic demands and estimated construction costs are more precisely forecasted. Thus, the results from CBA provide only limited information, the expected value, which the investment in the project could possibly misjudge.

In addition, the option to defer toll collection cannot be included in the CBA process. Thus, it is unrealistic to expect that nothings can be done to improve the project when the actual project situation is different from the situation in the planning stage. CBA, therefore, cannot be used to calculate possible strategies to limit loss when having an option to defer toll collection. As a result, the project is likely to be viewed negatively when evaluated using CBA.

4.7.2 Considering uncertainties but not the option to delay toll collection

CBA with sensitivity analysis can be used to observe the range of possible results caused by uncertainties. It can be seen that the project starts to be economical when the traffic demand is 20 % higher than the expected value or the construction cost is 10 % lower than expected. Thus, the decision is to abandon the project unless the construction cost can be reduced 10 % or there is confidence that traffic demand will be 20 % higher than the expected demand.

However, the probability of uncertainty actually occurring cannot be described by sensitivity analysis. Moreover, the probable scenarios are hard to set up due to the large number of combination cases that must be tested.

For CBA using simulation technique, the average NPV is estimated to be minus twenty billion yen. The CBA using simulation technique provides additional information that there is a probability of 34.1 % that the project may be economically performed. Thus, the decision makers would still abandon the project due to the high probability (65.9 %) that the project will be uneconomical.

In either CBA with sensitivity analysis or CBA using the simulation technique, options in management cannot be considered in the analyzing process. Thus, the value of the option to defer toll collection is overlooked, which results in an underestimation of the real value of the project.

4.7.3 Considering the option to delay toll collection but not uncertainties

By using CBA, which considers only the option to defer toll collection, the project is economical (NPV = 0) when the toll is not charged in the first year. Then, expressway users will be charged a toll from the second year of operation. However, considering the option to defer toll collection without uncertainties is also unrealistic. The result is valid only for the case that the actual traffic demand and construction cost is exactly the same as the estimated value in the planning stage. For other cases, it is usually expected that the actual values are different from the predicted one, in which the results from this technique cannot be explained.

4.7.4 Considering both uncertainties and the option to delay toll collection

When the option to delay toll collection is used, the average revenue from toll collection is decreased from 34.1 billion yen (no option) to 29.9 billion yen or 12.3 % as shown in Figure 10.

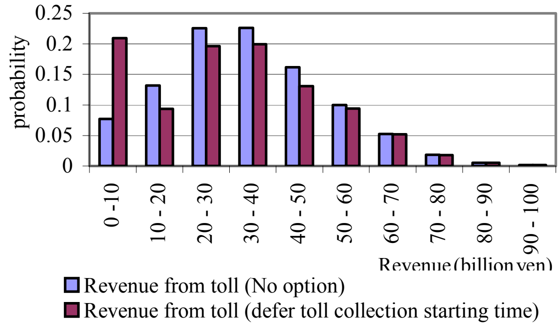

Figure 10. Comparison between revenue distributions

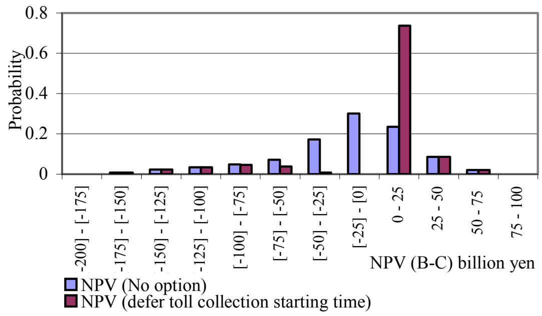

Figure 11. Comparison between NPV distributions

When the option is used, the average NPV is increased from minus twenty billion yen (no option) to –8.4 billion yen or 58 % as shown in Figure 11. Even though NPV is still a negative value, the probability that the project can be economical is increased from 34.1 %

(have uncertainties but no option) to 84.4 %. It is found that the effects of deferring toll collection reduces revenue by about 12.3 %, while the project NPV that can be economical is raised by 58 %. Thus, the decision is to invest in the project due to the high probability that the project can be economically performed, with some reduction in revenue collection.

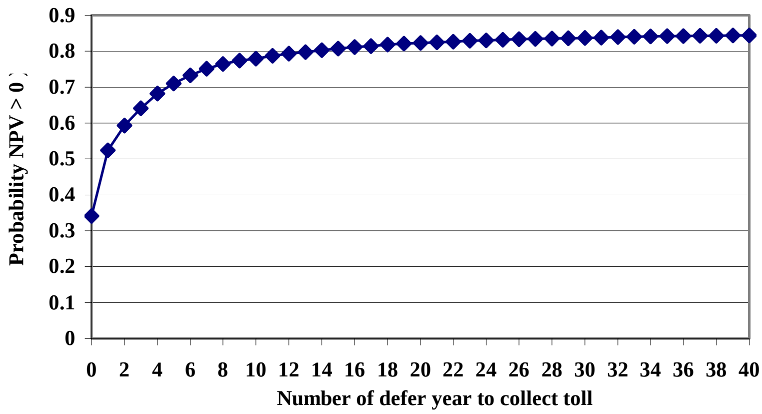

Figure 12. The probability that NPV > 0 when using option to defer toll collection

It can be seen that the probability that a project will become economical is greater when the number of years, that a toll is deferred, is increased. The probabilities range from 34.1 % in the case, when there has been toll collection since starting of service (toll deferred zero year) to 84.4 % in the case with no toll collection for the whole project (toll deferred 40 years). It can be seen from Figure 12. that the probability increases rapidly in the first 5 years (more than 70 % for the 5th year) of deferred toll collection and gradually increases after that. This means that if the managers have the right to defer toll collection in the project for the first 5 years, there is more than 70 % probability that the project will be economical. Thus, it is obvious that the option to defer toll collection is appropriate to be used in the early years after completion of the project. (within the first 5 years in this case). However, the managers have to determine the actual number of years that the project should be operated with no toll after the actual construction cost is revealed and the actual traffic demands are observed.

4.8 Recommendations using results from ROA

In the case study, the expressway project is evaluated by using various techniques. The results from each technique can lead to different decisions. A comparison of the results from various evaluation methods, and the recommendations are summarized in Table 3.

The Real Option Approach provides much more information than other evaluation techniques. The results show that even the average NPV is negative, –8.4 billion yen, however, the probability of the project being economical (if the right decisions are made) has increased to 84.4 %. This result is derived from the possibility to limit loss by using the option to defer toll collection. Thus, it is clear that the best decision is to invest in the project due to the high probability that the project can be viable.

When uncertainties and the option to defer toll collection are included in the evaluation process for an expressway project, it provides much more information about the investment risk for decision makers.

The more data is provided to decision makers, the more confidently a decision can be made. Sometimes this can totally change the decision whether or not to invest in the project.

Table 3. Summary of decisions from various evaluation methods

Evaluation methods	NPV (B-C) in billion yen	Probability that project NPV > 0	Year to defer toll collection	Decision
CBA	-15.2	No details	No details	Abandon
CBA with sensitivity analysis	-15.2	No details	No details	Abandon
CBA using simulation	-20	34.1 %	No details	Abandon
CBA with option to defer toll collection	0	No details	1 year	Invest
ROA	-8.4	84.4 %	Beginning period	Invest

5. Conclusions

Conventional CBA cannot be used to predict the effects of uncertainties and the option to defer toll collections in project evaluation. Thus, this study develops a framework to include uncertainties and the option to defer toll collection in the economic evaluation of an expressway project using the concept of Real Option Approach (ROA). The framework consists of modeling uncertainties in future traffic demand, modeling of uncertainties in construction cost, defining an option to defer toll collection in the expressway projects, and the calculation procedure employing the simulation technique.

The case study of Yoichi-Otaru expressway project in Japan was selected to demonstrate the procedure of the evaluation technique. Uncertainties in forecasting traffic demand and construction cost are modeled. Then, an option to defer toll collection is proposed as a strategy to limit loss when the future situation is worse than in the planning stage. Various techniques available for assessing an expressway project are used to evaluate whether the project should be implemented. When uncertainties are not considered, information for decision-making is limited, requiring reliance on just the average value of NPV. Thus, the project value is underestimated when the option to defer toll collection cannot be included in the analysis.

The results show that the decision for implementing the project is changed when uncertainties in future variables and the option to defer toll collection are introduced. The project would be abandoned in many cases when uncertainties and the option to defer toll collection are not included in the analyzing process. However, the project is more likely to be economical when the ROA is used in the evaluation process. It is found that the effects of the option to defer toll collection reduce revenue only by 12.3 %, while the probability that project NPV can be economical is raised by about 58 %. Thus, the decision to invest in the project becomes obvious due to high probability that the expressway could be economically maintained with some reduction in revenue collection.

It is also found that the option to defer toll collection is appropriate for use in the beginning of the project (i.e. within the first 5 years for this study). However, the managers must determine the actual number of years that the project should be operated with no toll after the actual construction cost is revealed and the actual traffic demand is observed.

It should be noted that the suggested process that applies the Real Option Approach in Cost-Benefit Analysis is not limited only to expressway project application. The Real Option Approach is also a recommended technique to be applied to other types of transportation projects.

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