Dynamic Strategic Planning for Transportation Infrastructure Investment in Japan

by

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ABSTRACT

This thesis applies Dynamic Strategic Planning (DSP) to transportation infrastructure investment in Japan. It focuses on the difference in project evaluations between the conventional and DSP-based cost-benefit analysis. It also analyzes policy issues in implementing DSP in Japan's Ministry of Transportation (MOT).

Today, the Japanese government faces criticism of its inefficient public works investments at both macro and project levels. To cope with this, MOT announced that it would incorporate cost-benefit analysis into its decision-making for investments in major new projects. While this movement in MOT is supposed to make its investments more efficient, conventional cost-benefit analysis does not systematically take into account future uncertainties and risks and can lead to wrong decisions.

DSP is the approach that takes into account future uncertainties and risks and insures managerial flexibility. It can maximize the expected net present value (NPV) of a project. In other words, it can minimize the loss of NPV caused by a failure to choose the best strategy.

A case study of a container terminal development in Japan introduces the problem of the conventional method and advantages of DSP. It demonstrates that project valuation based on DSP using decision tree analysis, the Black-Scholes equation, or Monte-Carlo simulation, is more precise than the conventional method. Also, DSP has advantages over the conventional method in terms of its ability to increase the real value of projects.

This thesis finally analyzes policy issues in implementing DSP in MOT, and recommends that MOT use DSP as a basis of its decision-making while the Ministry considers political issues.

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ACKNOWLEGEMENTS

It was very fortunate for me that I had an opportunity to work on this project under the supervision of Professor Richard de Neufville. On the first day of his class of Dynamic Strategic Planning (DSP), I was very impressed by the concept of DSP because it seemed to be an answer to my inquiry about how to make Japan's public infrastructure development more efficient. Professor de Neufville specializes in airport developing systems, and is also very familiar with Japanese situations. Only his precise, insightful, and patient advice was able to lead me to the completion of this project.

I would like to express my gratitude to my sponsor, Japan's National Personnel Agency, and my all superior officials in Japan's Ministry of Transportation who gave me this precious opportunity of studying abroad. This experience will be my property for the rest of my life.

I appreciate my colleagues in Japan's Ministry of Transportation, particularly Mr. Shigemoto, Mr. Shiota, Mr. Inoue, Mr. Okuda, and Mr. Hirakawa, who cooperated in my collection of Japanese data. It was definitely one of the most crucial parts in this project.

Finally, I would like to thank my parents for their genial encouragement during my stay in the United States.

INTRODUCTION

Investment by the Japanese government is required to be more efficient today than it used to be. For the past half-century, the Japanese government has almost continually invested in the nation's transportation infrastructure under the assumption that demand for it will increase rapidly. This government strategy has supported the healthy growth of the country. This situation, however, has changed. The economic growth of Japan in 1999 is not as strong as it used to be. The public sector is suffering from a huge budget deficit. Under such circumstances, some public works are being criticized as inefficient [Takemura 1996, Sumita 1998]. Accordingly, it is now very important to increase the efficiency of public investments.

Literature regarding project investment policy is abundant. Public Economics, for example, is an established field of study in which efficient government investment policy is discussed [Stiglitz 1988]. Cost-benefit analysis is one of the most popular approaches to making a decision on a project [Anderson and Settle 1977, Zerbe and Dively 1994]. In some advanced Western countries, such as Germany and the United States, cost-benefit analysis has sometimes been applied to decision processes [Morisugi and Kayahara 1998]. Furthermore, the study of corporate finance has developed the theory of optimal investment policy. Discounted Cash Flow (DCF) is one of the most important approaches to an investment decision in many private companies [Brealey and Myers 1996]. Recently, the value of "Real Options," i.e., the option value with investment opportunities in real assets, which is analogous to financial options, has been incorporated into DCF [Trigeorgis 1996, Amram and Kulitilaka 1999]. One of the most crucial issues in these approaches to making the optimal investment plans is how to deal with future uncertainties and risks. Dynamic Strategic Planning (DSP) is the approach that takes into account future uncertainties and risks and insures managerial flexibility. It maximizes the expected net present value (NPV) of a project. In other words, it minimizes the loss of NPV caused by a failure to choose the best strategy.

The Japanese government, however, has not systematically incorporated these project evaluation approaches into its decision-making process in public transportation infrastructure development. In Japan, the public sector (either the national government or local governments) usually assumes the authority to develop and operate major transportation infrastructures, such as roads, seaports, and airports, and there is no statute that requires the public sector to carry out an analysis of project efficiency, such as cost-benefit analysis. As a result, although private companies seriously examine project efficiency as a matter of course, this has not been the case with government projects. In addition, Japanese government investment has been usually based on a single best forecast, and, consequently, has been vulnerable with respect to future uncertainties. Japan's Ministry of Transportation (MOT) has started to undertake cost-benefit analysis when investing in major transportation projects. It has also instituted re-evaluation systems for ongoing projects. With this setup, MOT now hopes to ensure the efficiency of its investments. Although this arrangement seems to be the correct way to carry out efficient investment, MOT might fail in choosing the best strategy since it does not systematically take into account future uncertainties and risks.

This thesis analyzes both the current MOT system and DSP in investing in the transportation infrastructure in Japan. There are two major questions to be examined:

- Does DSP work better than the current system in terms of the efficiency of the transportation infrastructure investment in Japan?
- Should the Japanese government incorporate DSP into the transportation infrastructure investment?

This thesis contains five chapters and a conclusion. Chapter 1 introduces criticisms of the government's inefficient investments in Japan and efforts to make them more efficient. Chapter 2 examines the uncertainties and risks in transportation infrastructure investment, mainly using examples of Japanese transportation projects. Chapter 3 explains the concept and advantages of DSP and its project valuation methods, such as Decision Analysis, and Real Options. Chapter 4 is dedicated to a case study in which a container terminal development in Japan is evaluated by the DSP approach based on the cost-benefit analysis framework. After the analyses of the case study, Chapter 5 discusses issues in implementing DSP in Japan. The conclusion summarizes the findings of this thesis.

CHAPTER 1

CRITICISMS OF TRANSPORTATION INFRASTRUCTURE DEVELOPMENT SYSTEMS IN JAPAN AND EFFORTS TO MAKE THEM MORE EFFICIENT

The national government, mainly through either the Ministry of Transportation (MOT) or the Ministry of Construction (MOC), strongly controls transportation infrastructure developments in Japan. Accordingly, the methods used by MOT or MOC to implement policy aimed at making its investments more efficient are crucial for the overall efficiency of transportation infrastructure investments in Japan. This chapter first introduces criticisms of inefficient infrastructure investments in Japan, and then overviews Japanese transportation infrastructure development systems that might affect investment efficiency. Finally, this chapter examines efforts towards more efficient investments.

Criticism of Inefficient Investments

Today, the Japanese government faces criticism of its inefficient public works investments at both macro and project levels. When the national economy was growing rapidly, it was relatively easy to justify an investment because demand for the infrastructure was expected to be sufficient soon, if not immediately. The growth of Japan's economy, however, has stagnated recently, and the national budget has been suffering from a huge deficit. Under such circumstances, inefficient investments in public infrastructure have been severely criticized.

Criticism at Macro Level

During the past decade, the portions of the national budget allocated to each public works sector in Japan have remained almost the same (Figure 1-1). On the basis of this rigid budget allocation alone, some opinion leaders doubt that the overall efficiency of the government's investments is very high [Takemura 1996]. Such doubts have not remained purely a domestic matter. The U. S. journal *Business Week,* for example, has stated that years of wasteful public works spending have driven up Japan's gross debt level to 110 percent of the gross national product [Bremner 1999].

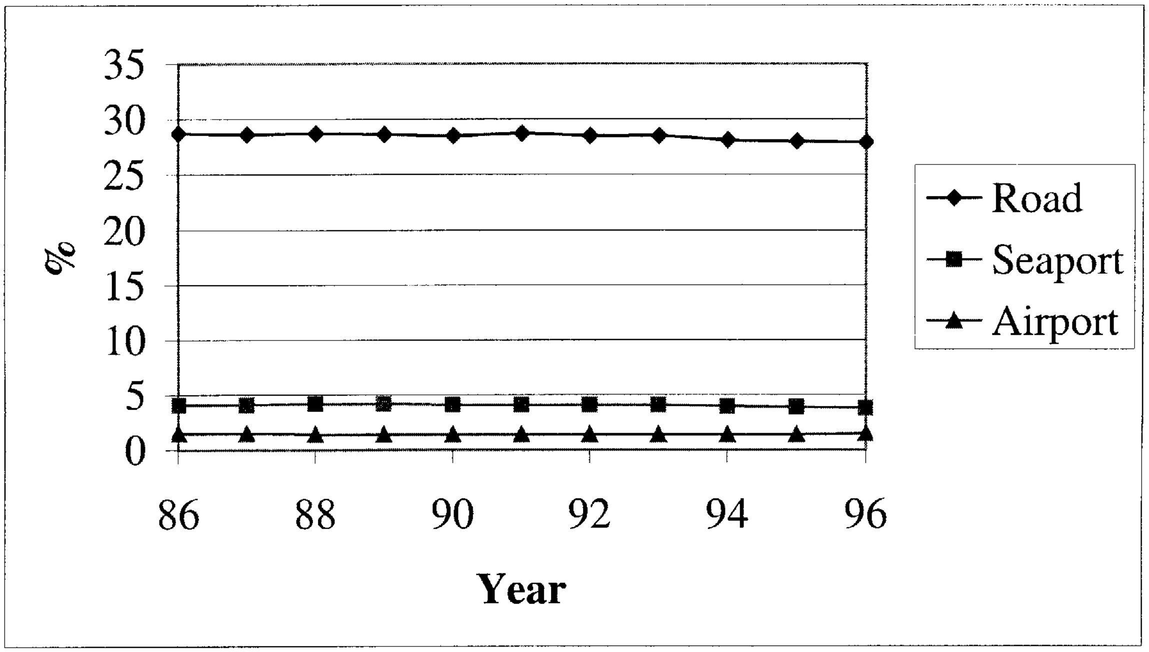
Criticism at Project Level

Some individual projects funded by the national government have been criticized as being oversized. Among these, the criticism of the Fukui Seaport Project is particularly hard on MOT. Sumita reports that the local people are calling this "a fishing pond costing ten billion Yen" because the level of berth usage is only around ten percent of the projection [Sumita 1998].

Transportation Infrastructure Development Systems in Japan

While the private sector is very sensitive to the cost-revenue soundness of its investments, the public sector is conscious about the equity of distribution as well as maximizing social benefits. In addition to this inherent nature of the government investment that might reduce the investment efficiency in terms of cost-benefit, the

Figure 1-1: Portions of the national public works budget allocated to major transportation infrastructure in Japan



Source: Takemura (1996)

established transportation infrastructure development systems in Japan might be "double-edged." That is to say, while the robust Japanese systems, such as the national government permission for master plans and the determination of investment five-year plans, are useful for stable realization of projects, they might create undesirable inflexibility in terms of investment efficiency.

Permission for Developments or Plans

Major transportation infrastructure developments usually must be authorized by the national government in the national economic plan, the national development master plan, and regional development master plans. Furthermore, in the case of airport developments, for example, a developer must adhere to the procedures shown in Figure 1-2 in carrying out its development plan. In the case of seaport developments, a developer must follow the procedures shown in Figure 1-3 in determining a seaport master plan. Usually, these procedures are rather time-consuming and burdensome, which might not only cause failure to develop facilities in a timely manner, but might also create a tendency to stick to the authorized plan regardless of changes in circumstances.

Investment Five-year Plans

The national government determines long-term development plans for most transportation facilities (Table 1-1). For example, MOT creates the Seaport Investment Five-year Plan, determining and adding up investments for seaport master plans

Figure 1-2: Procedures before developing an airport in Japan

1. Submission of application to develop an airport to the Minister of Transportation
2. Notification of the public about the application by the Minister
3. Public hearing held by the Minister
4. Examination of the application by the Minister
5. Approval of the development by the Minister
6. Notification of the public about development by the Minister

Source: Hirai (1984)

Figure 1-3: Procedures before authorizing a seaport master plan in Japan

1. Consultation on a plan by a Local Advisory Committee
2. Submission of the plan to the Minister of Transportation
3. Consultation on the plan by the Minister's Advisory Committee/ Examination of the plan by the Minister
4. Approval of the plan by the Minister
5. Notification of the public about the plan by the developer

Source: Fujino and Kawasaki (1981)

for the projected five year period. Sometimes making a five-year plan is a statutory mandate as is the case with the Seaport Investment Five-year Plan (required by the Seaport Development Urgent Measure Law), and sometimes it is not. Although most of the current five-year investment plans are not completely inflexible, it is difficult to initiate projects that are not incorporated into the plan during the five year period. This is particularly true in cases of seaports and airports because five-year plans related to these facilities designate individual seaports and airports to be funded during the five year period. This might also create a tendency to stick to the plan, making it difficult to expand and/or abandon planned projects.

Subsidies by the National Government

Whether the national government is the developer or not, it usually gives a significant amount of subsidies and/or loans to developers. This gives the national government strong control over developers. Furthermore, once developers get the subsidy, Article 18 of the Law Regarding Appropriate Enforcement of Subsidies, enacted in 1955, basically requires them to return all of this money if they abandon the project [Tokyo Horei 1997]. This might be one of the major reasons why it is very difficult for local governments to abandon projects even when the investment appears to be unwise. Consequently, local governments may have to stick to their original plans.

Efforts Towards More Efficient Investments

For roughly the past half-century, the investment in the transportation infrastructure in Japan has been intended to accommodate rapidly increasing demand in this sector. During the periods when the national economy was growing along with demand for all types of transportation, the cost-benefit efficiency of projects was not systematically analyzed in initiating the investment, although the economic multiplier effect of the project had sometimes been studied. The investment decision was supposed to be made so as to accommodate future demand based on a deterministic scenario created by the government [Sumita 1998]. Today, criticisms, such as those mentioned above, have driven the national government to increase the efficiency of its investments.

Cost-Benefit Analysis

Because the press, politicians, opinion leaders, and others are criticizing the inefficiencies of public investments, each ministry in the national government has launched its own efforts to cope with this issue. In March 1997 MOT announced that it would start cost-benefit analysis for its major new investments. MOT checks whether the Cost-Benefit Ratio of major new project exceeds one and also evaluates the Net Present Value of the project. Table 1-2 introduces major projects, benefit components, cost components, benefit evaluation periods, and the discount rate MOT applies to the analysis. Although the Ministry has not made public its detailed analytical methods, a former MOT director-general H. Kayahara has said, "The concept of probabilities, such as the probability that the volume of cargo will double in ten years, has not been incorporated into the analysis at all until now," implying that now MOT relies highly on a deterministic scenario in its analyses [Morisugi and Kayahara 1998].

Re-evaluation Systems for Public Works

In March 1998 MOT announced that it would start re-evaluation systems for its ongoing projects [1998b]. The Ministry will re-evaluate the effectiveness of a project five years after the budget appropriation is first authorized and apply cost-benefit analysis if necessary. As a result of the re-evaluation, MOT can change or abandon a project if warranted.

Table 1-1: Long-term development plans and their authority in Japan

Infrastructure	Long-term Plan	Authority
Railway	Regional railway master plans	The Minister of Transportation
	Shinkansen master plan	
Airport	Airport investment 5-yr. plan	
Seaport	Seaport investment 5-yr. plan	
	Seaport master plans	
Road	Road investment 5-yr. plan	The Minister of Construction
	City plans	
	Highway master plan	

Source: Doboku Gakkai (1991)

Table 1-2: Major projects and cost-benefit components Japan's Ministry of Transportation analyses

Project	Railway	New railway in recent developed town/ New underground rapid transit/ etc.
	Airport	New airport/ New runway (including expansion)
	Seaport	New deep-water berth
Benefit quantified		Reduced transportation cost/ Timesaving/ etc.
Cost quantified		Construction cost/ Operation cost/ etc.
Discount rate		4% per year
Benefit valuation period		30 - 50 years

Source: Japan, Ministry of Transportation (1997)

CHAPTER 2

UNCERTAINTIES AND RISKS IN TRANSPORTATION INFRASTRUCTURE INVESTMENT

The project evaluations made by Japan's Ministry of Transportation are based on a simple deterministic scenario. In the real world, however, transportation infrastructure investments face diverse uncertainties and risks. This chapter first presents cases in which there is the difference between forecasted demand and actual demand and then introduces those uncertainties and risks faced by the transportation infrastructure using a dichotomy: market uncertainties and project uncertainties.

Forecasted Demand and Actual Demand

It is very difficult to forecast future transportation demand accurately. In forecasting future transportation demand, usually many model specifications are constructed and compared with each other in order to obtain the specification that has the most rational explanatory powers. Even a model that fits past data very well, however, does not guarantee the accurate prediction of actual demand in the future.

Table 2-1 shows the difference between the forecasted demand for seaport cargo throughout Japan and actual demand. Each forecast, except for the last two, contains an error that is not negligible. Table 2-2 compares the forecasts for international air passengers throughout Japan, five years in advance, with the actual numbers, and Table

2-3 shows a similar comparison predicted ten years before the fact. As is the case with seaport cargo, most forecasts contain errors that cannot be ignored. In addition, the longer the forecasting perspective becomes, the larger the error tends to be.

The difficulty of forecasting also exists for individual projects. For example, although the forecast predicted that Kansai International Airport would accommodate 157,000 aircraft in 1995 [Japan, Ministry of Transportation 1981c], the actual figure was 107,000, or about two-thirds of the forecast [Kansai International Airport Company 1999]. Table 2-4, showing the case of annual passengers at the Tokyo International Airport (so-called Haneda Airport), indicates a similar discrepancy between the predicted and actual figures, an error that increases over a ten year span. The difficulty of forecasting is a universal problem, i.e., not peculiar to Japan. Table 2-5 shows a case in the United States. All of this implies that developers must recognize the risks when they rely totally on a simple deterministic forecast.

Uncertainties in Transportation Infrastructure Investment

Many factors can create a disparity between actual demand and forecasted demand. In addition to risks relating to demand, an investment in transportation infrastructure faces other types of risks, such as the increase of construction costs. Here, the dichotomy of market uncertainties and project uncertainties is applied to transportation projects.

Table 2-1: Actual and forecasted demand for seaport cargo throughout Japan (5-year perspective)

Year		Volume (100 million ton)		Error
Target	Forecasted	A. Actual	B. Forecast	C. B/A (%)
1965	1960	8.3	6.2	75
1969	1964	16.0	10.5	66
1972	1967	22.2	15.3	69
1975	1970	25.3	33.8	134
1980	1975	29.1	37.0	127
1985	1980	28.3	41.0	145
1990	1985	32.5	30.8	95
1995	1990	34.2	34.0	99

Error: B/A	%
Average	101
Average Deviation from 100%	25

Sources:

1. Actual Data: Japan, Ministry of Transportation (1998c)
2. Forecast: Japan, Ministry of Transportation (1991a, 1986a, 1981a, 1976a, 1971a, 1968, 1965, and 1961)

Note: Actual data use calendar year while forecasts use fiscal year.

Figure 2-1: Actual and forecasted demand for seaport cargo throughout Japan (5-year perspective)

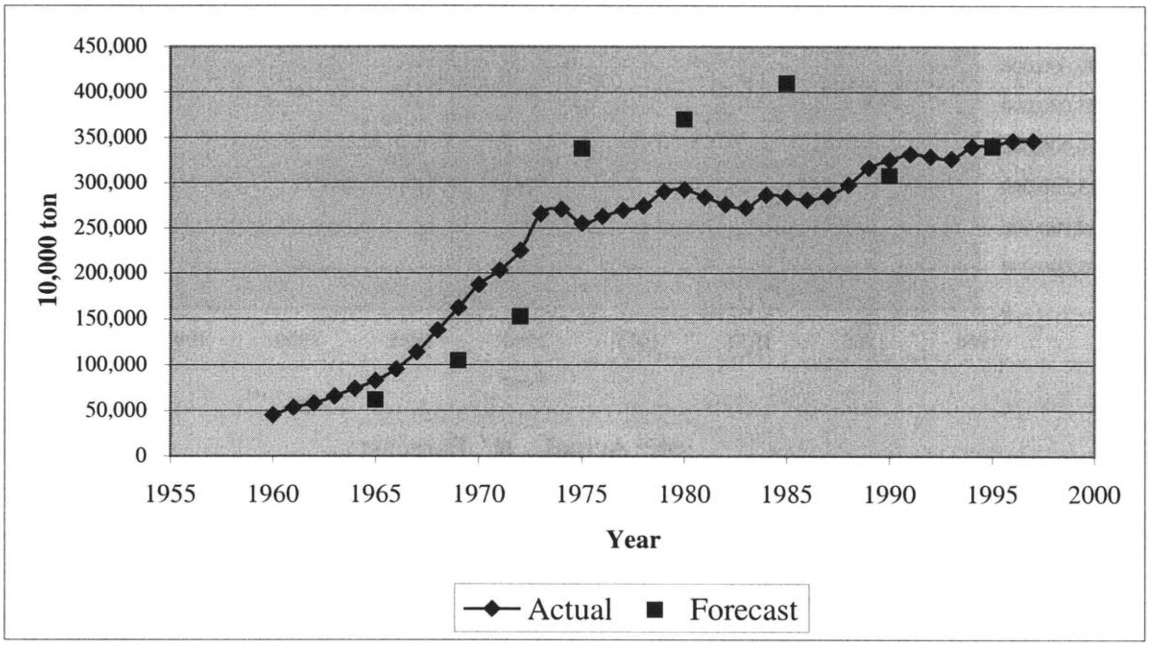


Table 2-2: Actual and forecasted demand for international air passengers throughout Japan (5-year perspective)

Year		Passenger (million)		Error
Target	Forecasted	A. Actual	B. Forecast	C. B/A (%)
1971	1966	4.3	3.5	81
1975	1970	7.9	10.0	127
1980	1975	12.1	15.0	124
1985	1980	17.6	25.5	145
1990	1985	31.0	27.0	87
1995	1990	43.6	45.0	103

Error: B/A	%
Average	111
Average Deviation from 100%	22

Sources:
1. Actual Data: Japan, Ministry of Justice (1998)
2. Forecast: Japan, Ministry of Transportation (1991b, 1986b, 1981b, 1976b, 1971b, and 1967)

Figure 2-2: Actual and forecasted demand for international air passengers throughout Japan (5-year perspective)

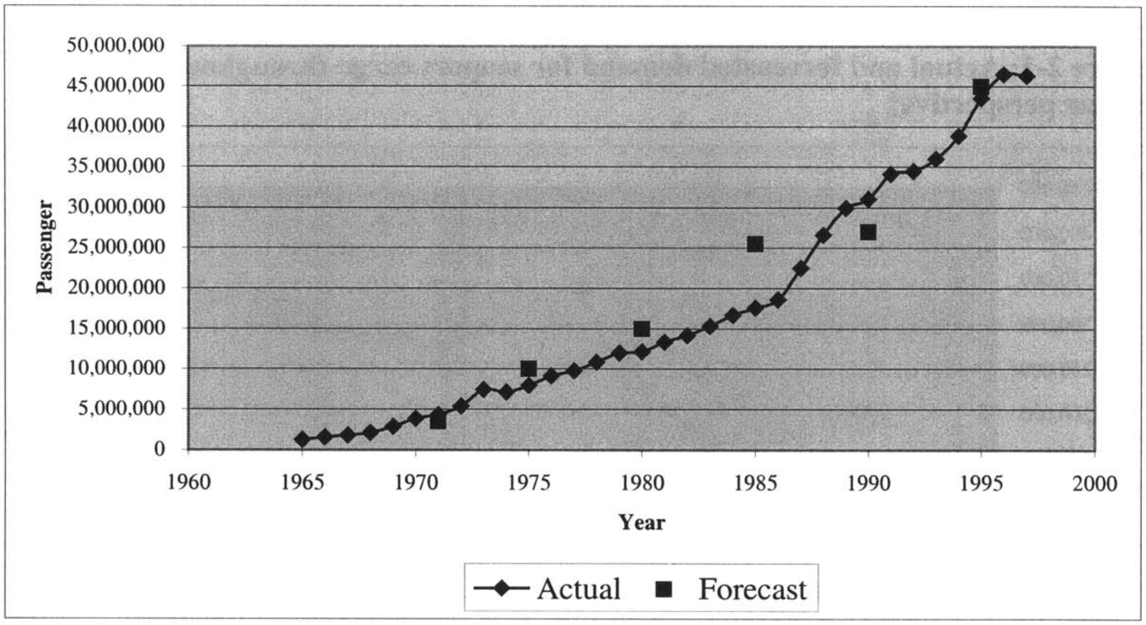


Table 2-3: Actual and forecasted demand for international air passengers throughout Japan (10-year perspective)

Year		Passenger (million)		Error
Target	Forecasted	A. Actual	B. Forecast	C. B/A (%)
1980	1970	12.1	20.0	165
1985	1975	17.6	27.0	153
1990	1980	31.0	39.5	127
1995	1985	43.6	37.9	87

Error: B/A	%
Average	133
Average Deviation from 100%	40

Sources:
1. Actual Data: Japan, Ministry of Justice (1998)
2. Forecast: Japan, Ministry of Transportation (1986b, 1981b, 1976b, and 1971b)

Figure 2-3: Actual and forecasted demand for international air passengers throughout Japan (10-year perspective)

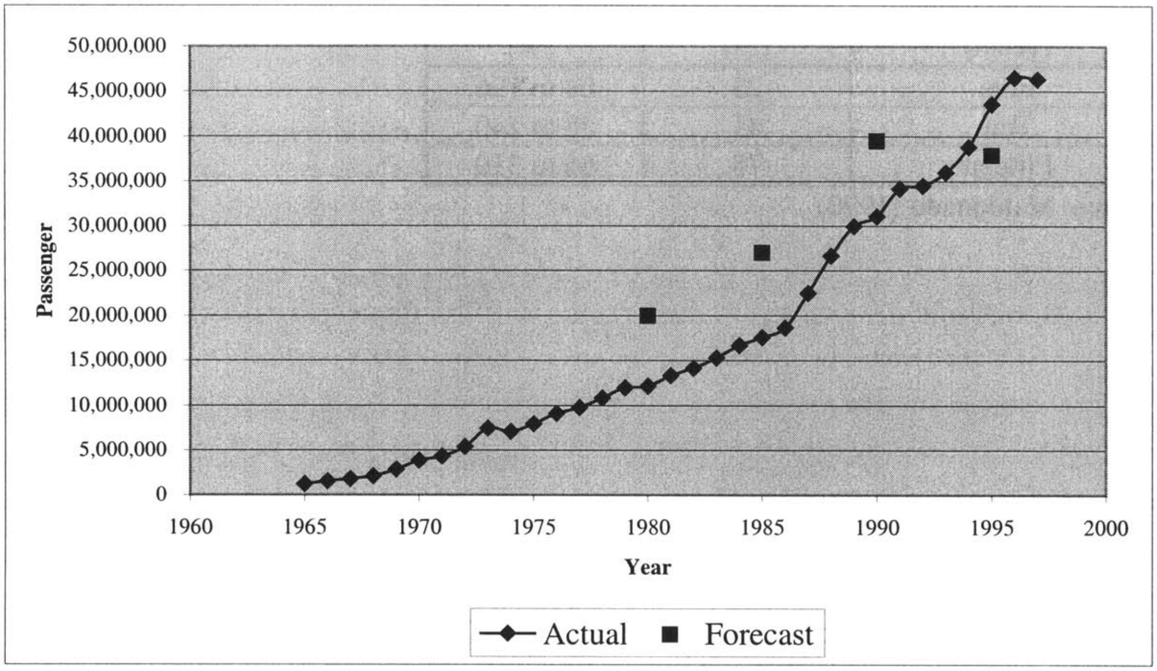


Table 2-4: Actual and forecasted demand for passengers at Haneda airport

Year		Passenger (million)		Error
Target	Forecasted	A. Actual	B. Forecast	C. B/A (%)
1985	1983	24.9	28.0	112
1990		38.9	43.0	111
1995		43.9	54.0	123

Error: B/A	%
Average	115
Average Deviation from 100%	15

Sources:

1. Actual Data: Japan, Ministry of Transportation (1998d)
2. Forecast: Japan, Ministry of Transportation (1983)

Table 2-5: Actual and forecasted demand for New England Region Airports

Planning Horizon (years)	Average Error (%)	Range of Errors (%)
Five	23	64 to 196
Ten	41	58 to 240
Fifteen	78	66 to 310

Source: Maldonado (1990)

Market Uncertainties

Market uncertainties are those that affect overall market conditions with respect to a transportation development plan. Risks resulting from these uncertainties cannot be avoided.

In terms of cost and benefit, the success or failure of a transportation infrastructure development depends mainly on the growth of demand. The growth of the corresponding market throughout Japan is supposed to significantly affect the demand growth for an individual project. The growth in the number of passengers throughout Japan, for example, may significantly affect the demand growth for an individual airport development project, and the growth in the volume of cargo throughout Japan may significantly affect the growth in demand for an individual seaport development project.

Apparently, there are many factors that affect overall national market growths. Below, four such factors are identified: GDP growth, technological innovations, contingent events, and currency markets.

- GDP growth

The national economic situation has a great impact on transportation demand. Usually, there is a strong correlation between GDP and transportation demand. Accordingly, in forecasting future transportation demand, GDP is often used as an explanatory variable. If GDP does not grow as expected, forecasts will tend to overestimate actual demand. In periods during which GDP grew more than expected, the number of both national airport passengers and national seaport cargoes generally grew more than forecasted. In contrast, during those periods in which GDP grew less than expected, the opposite was true (Table 2-6, and Figures 2-1, 2-2, and 2-3).

- Technological innovations

Apart from the economic situation, technological innovations sometimes drastically change the structure of transportation demand. The advent of air travel, for example, drastically decreased the need for international passengers to travel by sea. The emergence of container transportation systems also drastically decreased the volume of general bulk cargo.

- Contingent events

Contingent events sometimes significantly affect transportation demand. Two examples are illustrative: two oil crises, and the Gulf War. Oil crises of 1973 and 1979 seemed to have negative impacts on seaport cargo in Japan (Figure 2-1). In addition, the Gulf War of 1991 seemed to have a negative impact on international air travel.

- Currency markets

While a strong yen is supposed to increase imports and travelers going abroad, a weak yen is supposed to increase exports and travelers coming to Japan.

Table 2-6: Actual and planned GDP for Japan

Year		GDP growth rate (%)		Error
Period	Planned	A. Actual	B. Planned	C. B/A (%)
1961-70	1961	10.1	7.2	71
1964-68	1964	10	8.1	81
1967-71	1967	9.9	8.2	83
1970-75	1970	5.5	10.6	193
1973-77	1973	3.6	9.4	261
1976-80	1976	4.4	6	136
1979-85	1979	3.7	5.7	154
1983-90	1979	4.3	4	93
1988-92	1988	4.2	3.75	89

Error: B/A	%
Average	129
Average Deviation from 100%	47

Sources:
1. Actual: Japan, Economic Planning Agency (1996)
2. Plan: Japan, Chiiki Seibi Kodan (1995)

Note: Actual data use calendar year while plans use fiscal year.

Project Uncertainties

Project uncertainties are those that affect an individual project only. Investing in various projects can diversify the risks resulting from these uncertainties.

Apart from market uncertainties, each individual project faces various uncertainties both at its construction stage and at its operation stage.

1) Construction stage

- Construction costs

The most typical project risk in transportation infrastructure development may be the increase of construction costs. In the case of the Kansai International Airport, the estimated cost before the construction was around 1 trillion Yen, while the actual cost turned out to be about one and a half time this much [Gekkan Doyu Sha 1994]. Table 2-7 shows four examples of construction cost uncertainties in recent major container terminal developments in Japan.

- Construction schedule

In addition to construction costs, a construction schedule also contains uncertainty. For example, the inauguration of Kansai International Airport was delayed more than a year because of ground subsidence. In the case of Narita airport, the second runway construction has not been developed yet because of the difficulty in purchasing

Table 2-7: Estimate and actual cost of container terminal construction in Japan (unit: 10^8 Yen)

Seaport	Terminal	A. Actual	B. Estimate	A/B(%)
Y	1	142	149	95
	2	136	150	91
K	1	170	147	116
	2	243	179	136

Error: A/B	%
Average	109
Average Deviation from 100%	16

Source: Japan, Ministry of Transportation (1999a) the runway site, although the Japanese government has desired to do so for almost three decades [Koku Shinko Zaidan 1997].

2) Operation stage

As it has been mentioned in the section on market uncertainties, the success or failure of a transportation infrastructure development mainly depends on the growth in demand. Apart from the growth of demand in the national market as a whole, each individual project faces demand growth uncertainties specific to itself. In some projects, rates of demand growth might be greater than the rate of demand growth for the entire national market, and in some projects, they might be smaller.

There appear to be many factors that affect the growth in demand for an individual project. Below, two factors are identified: regional socioeconomic conditions and the level of service accomplished by the transportation infrastructure. These two factors are somewhat interrelated.

- Regional socioeconomic conditions

Hinterland conditions for transportation infrastructure to be developed are not homogeneous throughout Japan. In some regions, the rates of gross regional product (GRP) growth might be greater than the rate of GDP growth for the entire country. This might also be true for rates of population growth. These factors may create a deviation in demand growth for a particular project from that of the national average. Furthermore, in the case of the volume of cargo, for example, the development of an industrial complex in a region may significantly affect the demand growth for a container terminal to be developed.

- The level of service

The level of service accomplished by an individual project, such as the frequency of services, is one of the key factors that determine the attractiveness of the transportation infrastructure developed. Even though a newly developed transportation infrastructure may have advantages over existing infrastructures in terms of access cost and access time for users in its potential hinterland, demand would not be realized if the level of service were low. Airports that have more frequent flights and more diverse destinations, for example, are likely to attract more passengers than those that do not. Seaports that have more frequent liner services and more diverse destinations attract more cargo than those that do not.

Although the level of service accomplished by a transportation infrastructure is not totally independent of the factors introduced in the section on regional socioeconomic conditions, the success of an airport or a seaport authority in port sales sometimes affects the result. For example, if the port authority succeeds well in port sales, it can capture a large portion of its potential hinterland passengers or cargoes, and vice versa.

CHAPTER 3

EVALUATING TRANSPORTATION INFRASTRUCTURE INVESTMENT USING DYNAMIC STRATEGIC PLANNING

This chapter presents the concept and advantages of Dynamic Strategic Planning (DSP) using the example of an airport investment. This simple example was arbitrarily created in order to explain the concept and advantages of DSP as well as the defects of Net Present Value (NPV) based on a deterministic scenario. This chapter also introduces two major Real Options valuation methods: the Black-Scholes equation and Monte-Carlo simulation.

Imaginary project (Figures 3-1, 3-2, and 3-3)

- An airport authority (AA) is deciding on an investment strategy for an airport (AP).
- The AP master plan contains three identical runways.
- The construction cost of each runway is $500 million. The construction of a runway takes AA only one year.
- If the demand for AP is high, medium, or low, respectively, AP provides the net benefit of $100 million, $50 million, or $25 million, respectively, for the first operation year. The three outcomes are equally plausible. The annual net benefit is supposed to increase 20%/year regardless of the net benefit of the first year.
- Because of the capacity, each runway can provide the net benefit of $100 million per year at most.

Figure 3-1: Assumptions of imaginary project

Discount rate	4%

Construction cost	$500 million/RW

Net Benefit		
Growth rate	20% /year	
Initial net benefit	High	$100 million
	Medium	$50 million
	Low	$25 million

Maximum Benefit	$100 million/year/RW

Figure 3-2: Schedule of imaginary project

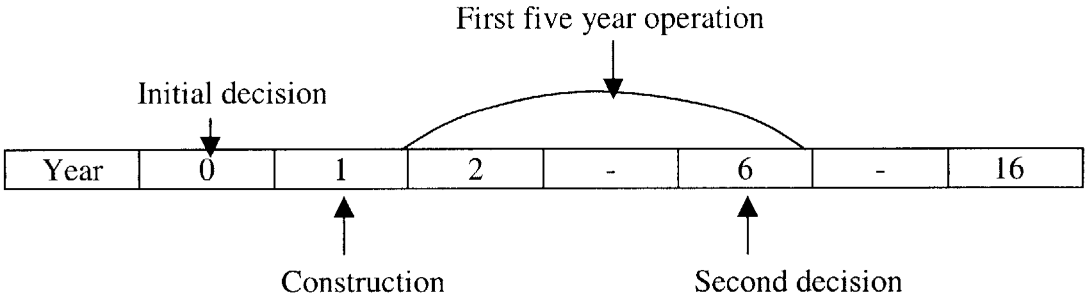
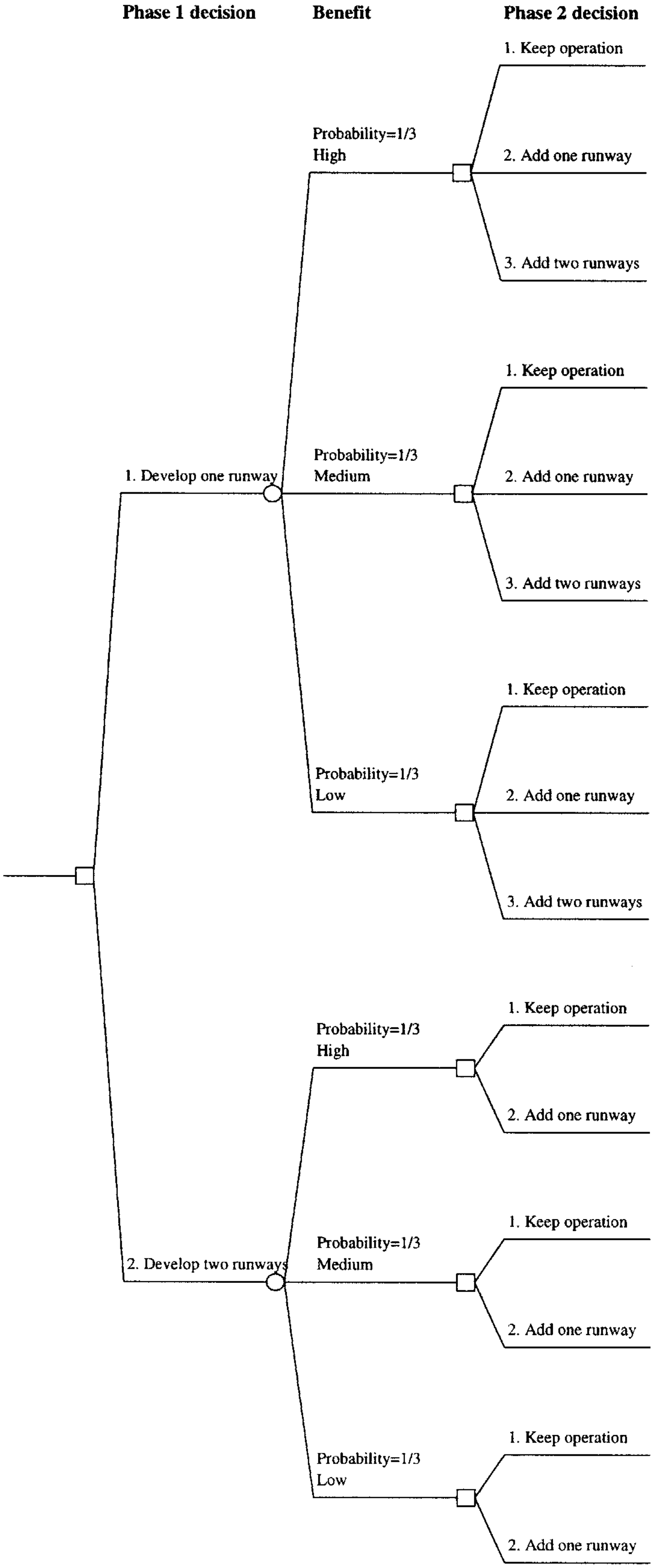


Figure 3-3: Decision structure of imaginary project



- If AA first develops two runways, it will have the opportunity to add one runway after five years of operation. If AA first develops one runway, it will have the opportunity to add one runway or two runways after five years of operation.
- AA evaluates the project for 16 years (one year construction and 15 year operation) using a 4% discount rate.

NPV based on a deterministic scenario (simple NPV)

The simple NPV is calculated as follows:

$$NPV = \sum_{t=1}^{16} \frac{Benefit_t - Cost_t}{(1+0.04)^t}$$

Suppose AA totally relies on the medium scenario (deterministic scenario). The simple NPV of the development of two runways, \$525 million, is greater than that of one runway, \$471 million. Based on this deterministic scenario, AA would decide to start developing two runways (Figure 3-4).

Expected NPV taking into account uncertainties (Base Expected NPV)

Even if AA's decision were based on the expected NPV taking into account uncertainties in the net benefit, AA still would decide to start developing two runways because the expected NPV of the two runway development, \$509 million, is greater than that of the one runway development, \$441 million (Figure 3-5). (In this thesis, ***Base Expected NPV*** is defined as the expected NPV of an initial investment without considering expansions.)

Figure 3-4: Simple NPV based on a deterministic scenario (unit: $million)

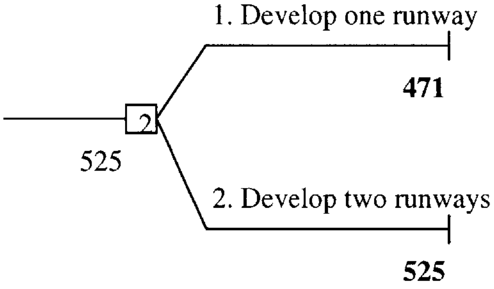
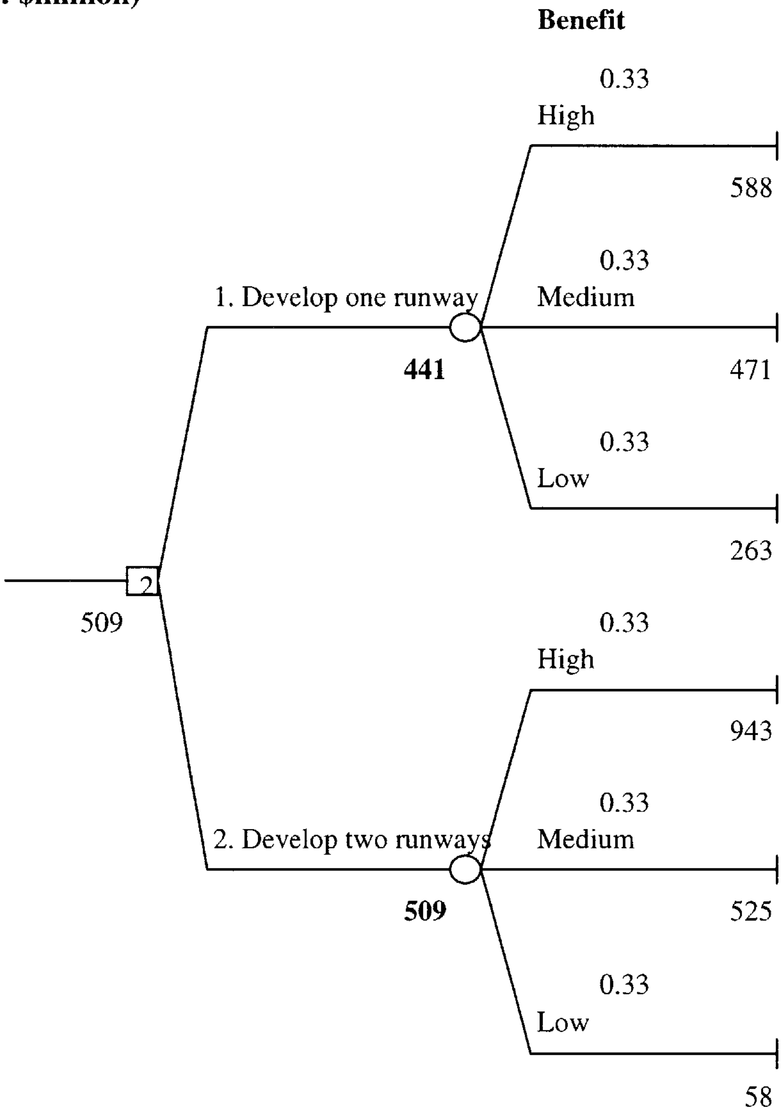


Figure 3-5: Expected NPV taking into account uncertainties (Base Expected NPV, unit: $million)



Here, the expected NPV of the initial investment (Base Expected NPV) is smaller than that of the deterministic scenario. This is not a universal property. This happens because of asymmetric outcomes around the medium outcome.

Dynamic Strategic Planning

DSP is the approach that takes into account future uncertainties and risks and insures managerial flexibility. Applying DSP to the project evaluation, neither of the two NPV valuations is correct. AA should recognize the Real Options value of adding one or two runways. If AA first develops two runways and the benefit is high, for example, it should add one runway after the five years of operation because the resulting NPV, $1,127 million, is greater than the NPV without adding it, $943 million; if the benefit is medium or low, however, it should not add one runway (Figure 3-6). Assuming each outcome occurs equally, the option value of having the other runway development project is $61 million (Table 3-1: Initial decision 2).

The essence of DSP is evaluating multiple stage decisions. Here, there are decision opportunities at two stages: the initial decision and the decision at the end of the five years of operation. Taking into account the option value, the ***Total NPV*** of initially developing one runway, $608 million, is greater than that of initially developing two runways, $570 million. This implies that, if the objective function of AA is to maximize the NPV, DSP increases the value of the project by $38 million.

Figure 3-6: NPV based on Dynamic Strategic Planning (unit: $million)

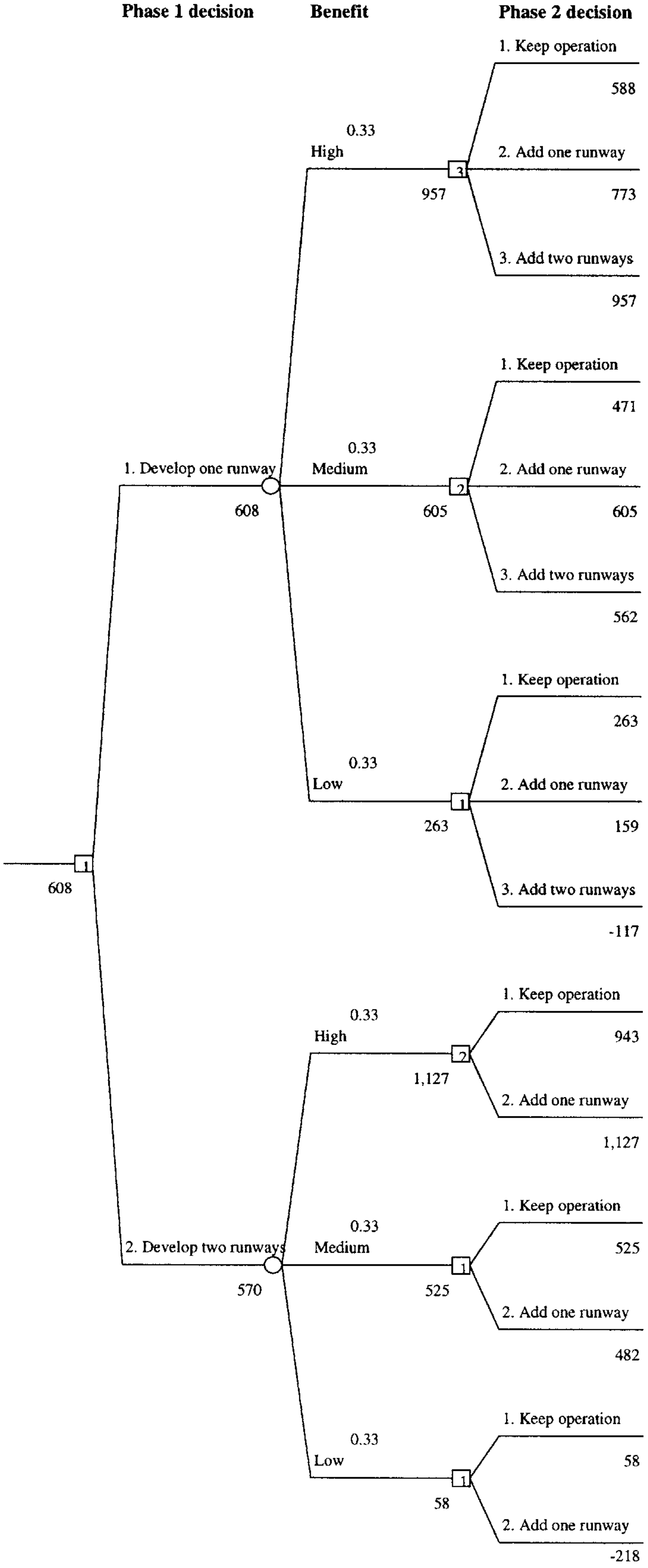


Table 3-1: Total NPV Including Option Value (unit: $million)

▨ Decision taken in second period

Initial decision: 1. Develop one runway

Benefit Outcome	Second decision			**Option value**
	Keep Operation	Add one runway	Add two runways	
High	588	773	▨ 957	369
Medium	471	▨ 605	562	133
Low	▨ 263	159	-117	0

Total NPV, $608 million = ***Base Expected NPV****, $441 million (=(588+471+263)/3)

+ ***Option Value***, $167 million (=(369+133+0)/3)

****Base Expected NPV***: Expected NPV of Phase1 investment without Phase 2 investment

Initial decision: 2. Develop two runways

Benefit Outcome	Second decision		**Option value**
	Keep Operation	Add one runway	
High	943	▨ 1127	184
Medium	▨ 525	482	0
Low	▨ 58	-218	0

Total NPV, $570 million = ***Base Expected NPV***, $509 million (=(943+525+58)/3)

+ ***Option Value***, $61 million (=(184+0+0)/3)

Option calculator

In this example, the option value is calculated based on three discrete outcomes that are equally plausible regardless of whether AA invests in one runway or two runways using decision tree analysis. In the real evaluation, however, the situation might be more complicated. Amram and Kulatilaka introduce the following three general solution methods of Real Options: PDE (Partial Difference Equation), Dynamic Programming, and Simulations (Figure 3-7) [Amram and Kulatilaka 1999]. This chapter introduces the Black-Scholes equation (PDE) and Monte-Carlo simulation that become useful tools for the case study in the next chapter.

PDE/Black-Scholes equation

- Black-Scholes equation

The PDE approach solves a partial differential equation that equates the change in option value with the change in the value of the tracking portfolio [Amram and Kulatilaka 1999]. Among PDE approaches the Black-Scholes equation is popular because it provides a simple solution and a quick answer when appropriate. The equation is:

$$V = N(d1)*A - N(d2)*X*\exp(-rf*T)$$

Here,

V = Current value of call option

A = Current value of underlying asset

X = Cost of investment

rf = Risk-free rate of return

T = Time to expiration

N(d1) and N(d2) are the values of the normal distribution at d1 and d2

$d1 = [\ln(A/X) + (r + 0.5*\sigma^2)*T]/(\sigma*T^{0.5})$

$d2 = d1 - \sigma*T^{0.5}$

σ = Volatility of the underlying asset

The Black-Scholes equation is applicable to this airport development example because this project can be seen as a project having a European call option that can be exercised at the end of year six (expansion option). Applying the Black-Scholes equation to the example, each variable is defined as follows:

A = Expected value of additional net benefit flow by adding one or two runways in the year of second decision, the year six (Current value of underlying asset). Precisely,

$$A = \sum_{t=8}^{16} \frac{\Delta Benefit_t}{(1+0.04)^{t-6}}$$

Here,

ΔBenefit = Net benefit with runway addition
– Net benefit without runway addition

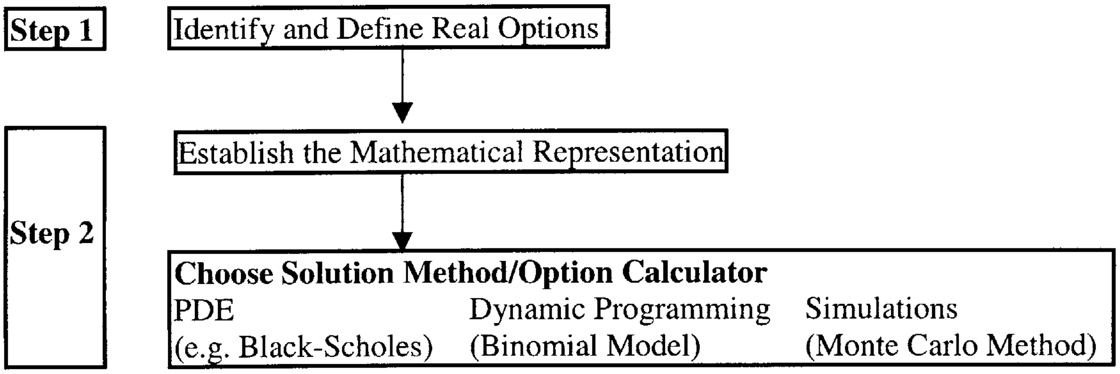
X = Construction cost of one or two runways

rf = 4% (assumption)

T = 6 years (one year for construction of the initially invested runway and five years of operation)

σ = Volatility of the underlying asset

Figure 3-7: Solution Methods and Option Calculators



Source: Amram and Kulatilaka (1999)

- Option value in decision 2

Because of the ease of explanation, the option value in decision 2 is calculated first. Here, three cases defined above (high, medium, and low net benefit) are used in valuing the underlying asset (additional net benefit by adding a runway on two runway airfield) and determining its volatility. When AA initially invests in two runways, the expected value of three cases can be seen as the current value of the underlying asset (Table 3-2). The value of each case (high, medium, or low) can be seen as a value that the underlying asset can have at the year six. Then the ratio of each value to the expected value is calculated. Standard deviation of the distribution of natural log of these ratios is assumed as six-year volatility. Annual volatility is obtained by dividing it by six.

Then, using necessary information as input of the Black-Scholes equation, the option value of adding a runway on two runway airfield is obtained (Table 3-3).

- Option value in decision 1

The option value of two additional runways when one runway is initially developed is the sum of the option value of adding a runway on one runway airfield and the option value of adding a runway on two runway airfield (the latter value is calculated above). The former value is calculated as the same way of the latter (Table 3-4, and 3-5).

It should be noted that this value is different from the option value of adding two runways on one runway airfield because AA does not have to simultaneously add two runways always. Thus, the option value of one additional runway when two runways are initially developed (decision 2) is \$81 million, and that of one or two additional runways when one runway is initially developed (decision 1) is \$226 million, the sum of \$144 million and $81 million as explained. Both are similar to values estimated by the decision tree analysis (Table 3-6).

Simulation/Monte-Carlo Method

The simulation approach averages the value of the optimal strategy at the decision date for thousands of possible outcomes. (A representation of a system at a particular point in time is usually referred as a Monte-Carlo simulation [Winston 1994].) In this method, the optimal investment strategy at the end of each path is determined and the payoff is calculated. The current value of the option is found by averaging the payoffs and then discounting the average back to the present. This method can handle many aspects of real world applications, including complicated decision rules and complex relationships between the option value and the underlying asset [Amram and Kulatilaka 1999]. One of difficulties with Monte-Carlo simulation is specification of the probabilities for different results for each of the variables [Zerbe and Dively 1994].

Table 3-2: Volatility of underlying (adding a runway on two runway airfield)

	Asset value ($million)	Ratio to Expected value	Ln (Ratio)
Expected	424		
Low	132	0.311	-1.169
Medium	426	1.006	0.006
High	714	1.683	0.521

Volatility (6 yrs.)	86.6%
Annual Volatility	14.4%

Table 3-3: Option value of adding a runway on two runway airfield

A	$424M
X	$481M
rf	0.04
T	6 yrs.
σ	14.4%

d1	N(d1)	d2	N(d2)
0.486	0.687	0.133	0.553

Call Value	**$81M**

Table 3-4: Volatility of underlying (adding a runway on one runway airfield)

Case	Asset value ($million)	Ratio to Expected value	Ln (Ratio)
Expected	508		
Low	159	0.313	-1.161
Medium	650	1.279	0.246
High	715	1.408	0.342

Volatility (6 yrs.)	84.1%
Annual Volatility	14.0%

Table 3-5: Option value of adding a runway on one runway airfield

A	$508M
X	$481M
rf	0.04
T	6 yrs.
σ	14.0%

d1	N(d1)	d2	N(d2)
1.016	0.845	0.673	0.749

Call Value	**$144M**

Table 3-6: Comparison of option values by two methods (unit: $million)

Decision	Option Value	
	Decision Tree	Black-Scholes
1	167	226
2	61	81

CHAPTER 4

CASE STUDY: EVALUATING A CONTAINER TERMINAL DEVELOPMENT IN JAPAN

This case study analyzes an actual container terminal development project in Japan. The objective is to construct a model helpful to Japan's Ministry of Transportation (MOT) in evaluating projects using the Dynamic Strategic Planning (DSP) approach. Recognizing uncertainties and risks in projects and insuring decision flexibility, MOT will be able systematically to find an optimal investment strategy in terms of maximizing the Net Present Value (NPV) of a project. After the valuation of case study, this chapter discusses what the government should consider in order to effectively use DSP.

Presentation of the project for case study (Figures 4-1, and 4-2)

The project is to develop container berths in seaport A located in prefecture B, which had no container berths. The seaport master plan was officially authorized in 1992 (Year 1). The plan was to develop a –10m berth and two –14m berths. In Year 1, the port authority of Port A and MOT jointly started constructing a –10m berth and one of the two –14m berths (Phase 1). (This means that major decisions, such as the details of the budget, were made in 1991 [Year 0].) After five years of construction, at the end of 1996, the two berths were put into year around operation. There is no plan to start constructing the other –14m berth (Phase 2) now.

Figure 4-1: Simplified configuration of the project

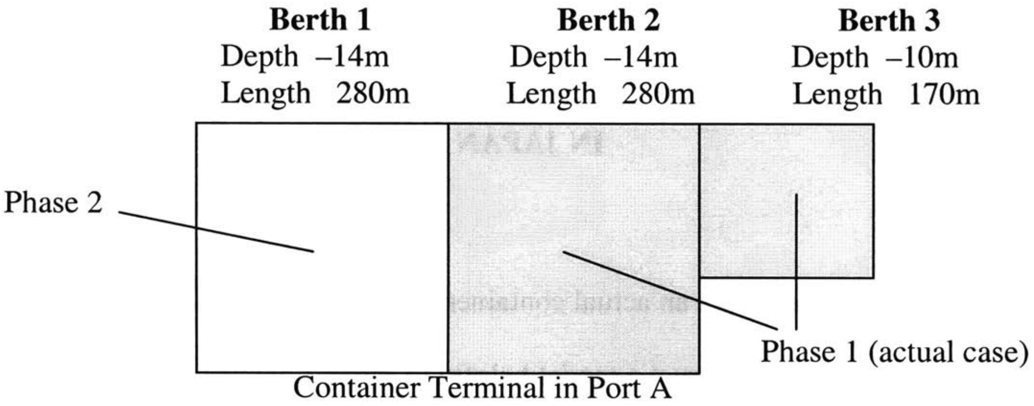
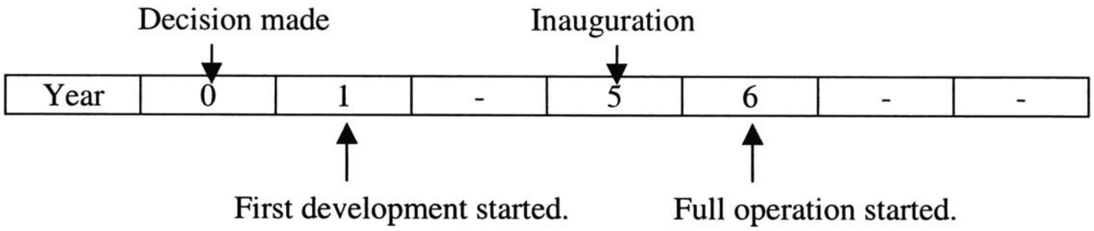


Figure 4-2: Schedule of the project (Phase 1)



Case study model and NPV valuation

Step 1. Construct Cost-Benefit Model

Framework of Model

Figure 4-3 illustrates the basic structure of the cost-benefit analysis. This model is the basis for calculating the Net Present Value (NPV) for both the current MOT valuation (conventional cost-benefit analysis) and the proposed DSP valuation. Appendix 1 gives detailed explanations of the model.

Horizon of analysis

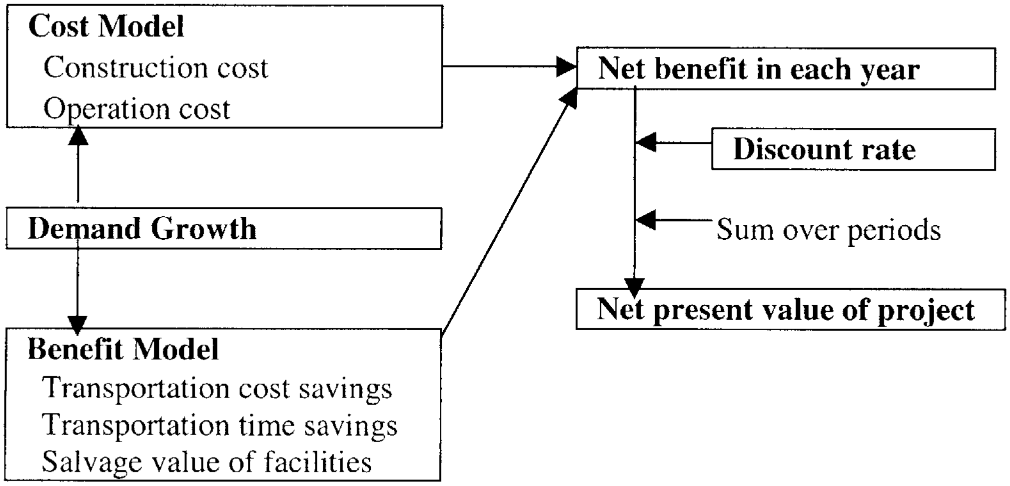
The benefit valuation period is set as 30 years because MOT uses this for container terminal development projects. Thus the total analysis period, including the construction stage, is 35 years.

Simple NPV based on a deterministic scenario (Current MOT's approach)

The NPV only for Phase 1 (without Phase 2 investment) is calculated based on a deterministic scenario. (Here, medium cases are used as the deterministic scenario for all uncertainties.) This is the conventional cost-benefit analysis that MOT now basically uses in evaluating projects. The resulting NPV for this phase 1 is positive, **10,185 million Yen**, so this investment is justifiable by the current MOT criterion (Appendix1: Table A1-5).

Actually, under current circumstance, MOT decides what scenario to use for the deterministic case. While MOT carries out sensitivity analyses to deal with future uncertainties and risks, there is no guarantee that these systematically lead MOT to optimal investment strategies.

Figure 4-3: Framework of the Cost-Benefit Model



Step 2. Identify uncertainties and risks

Market uncertainty

The growth in demand for container cargo throughout Japan was chosen here to represent a market uncertainty. It is assumed that Port A's potential hinterland demand growth will be the same as the national demand growth. Using the latest ten year data throughout Japan, the average growth rate of the container cargo market is 5.9%/year (the medium case), with the standard deviation of 2.4%/year growth rate (Table 4-1 and Appendix 2-2).

Project uncertainty

- Construction stage

Construction cost is one of the major sources of project uncertainties. Here, using the data in Table 2-7 and assuming that the ratio of actual to estimated cost is lognormally distributed, the Bracket-Median Method gives three discrete percentages of actual to estimated cost (high case: 129%; medium case: 108%; low case: 90%) [Neely 1998]. Each case has equal probability (Appendix 2-1). The original data obtained are assumed as being for a medium-cost case.

- Operation stage

The port's market share in the potential hinterland (the ratio of the container volume handled at the terminal to the total in the hinterland) was chosen to represent a project uncertainty at the operation stage. Whether the port authority succeeds in port sales or not may affect the share the port acquires. Observations of two similar seaport projects imply there are two stages of uncertainties (Appendix 2-3). The average share each port acquires during first five years of operation is 9.9%, with the standard deviation of 7.4% share. (The distribution of this share is then assumed as being lognormal.) After five years of operation, using the data of the two similar seaports, the port is expected to gain an additional 2.4 % of share each year on average (the medium case), with the standard deviation of 0.5%/year share.

Step 3. Identify strategic opportunities and options

1st decision at Year 0 (for Phase 1)

This section explores two kinds of investments for Phase 1. The first is to build only one –14m berth (Choice 1). This is not the actual case but an alternative investment that might have been better in terms of the NPV. The second choice is to build one –10m berth and one of two –14m berths as is the case with the actual investment (Choice 2). (Figure 4-4). (Investing in only –10m berth could also be an alternative; however, because a –14m berth is advantageous for a seaport in terms of simple capacity and types of ships accommodated, and because the purpose of this case study is to demonstrate DSP, the case simplifies the choices.)

2nd decision at Year 10 (for Phase 2)

At the end of Phase 1 (Year 10, the last year of the second five year seaport investment plan after Year 0), MOT will have the opportunity in Phase 2 to start an additional investment during the next Seaport Investment Five-year Plan (Figure 4-5). The decision for Phase 2 depends on the outcome of Phase 1. Decision-makers can take advantage of information on the Phase 1 construction cost and the demand growth from Year 6 to Year 10 during the first five years of operation. The information on construction cost is assumed as being perfect information, i.e., if the construction cost is high, medium, or low, respectively, for Phase 1, the construction cost for Phase 2 will also be high, medium, or low, respectively. (This is not necessarily real; however, geological conditions seem to explain significant portions of the uncertainty in marine construction, accordingly, the information of adjacent terminal cost can be very useful.) No resolution of the market uncertainty (the national market growth) is assumed here. Both market and project uncertainties in demand remain after Year 11. The information on project demand for the first five years of operation is not perfect information. Nevertheless, the information on the share acquired during Phase 1 is helpful for decision-makers to determine what strategy they should take for Phase 2. It is interpreted that Real Options for expansion can be exercised at the end of the second Seaport Investment Five-year Plan here. Figure 4-6 illustrates simplified decision structure.

Decision Tree Analysis

Before proceeding to a precise Real Options valuation, a simplified decision tree analysis is carried out to help decision-makers understand the essence of DSP. Three outcomes of construction costs have been already defined above. Applying the Bracket Median method to the demand uncertainties in Table 4-1, three outcomes for each demand uncertainty are calculated as equally plausible scenario (Table 4-2, and Appendix 2). Then, three outcomes of demand growths are created by convoluting three outcomes of market demand growths and three outcomes of project shares (Appendix 3).

Table 4-1: Summary of uncertainties

Type	Uncertainty	Statistic	%	Note
Market	Market Growth	Average	5.9	annual growth rate
		Standard Deviation	2.4	around Average
Project	Construction Cost	High case	129	of estimated cost
		Medium case	108	
		Low case	90	
	Port Share (base) (first 5-yr operation)	Average	9.9	of potential hinterland
		Standard Deviation	7.4	around Average
	Port Share (after 5-yr operation)	Average	2.4	annual additional share to base share
		Standard Deviation	0.5	around Average

Figure 4-4: Choice for Phase 1 (at Year 0)

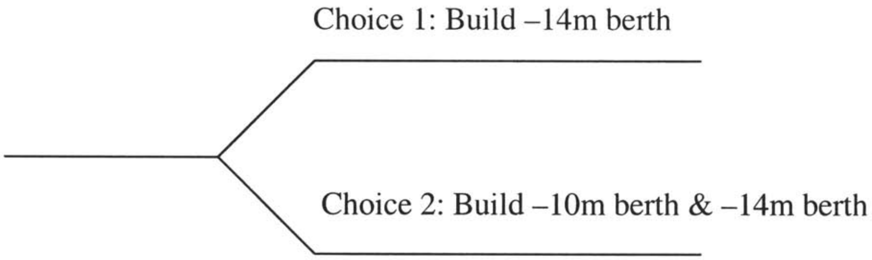


Figure 4-5: Strategic decision opportunities

5 yr. plan		1st	2nd	3rd	4th-7th
Year	0	1 - 5	6 - 10	11 - 15	16-35
Phase		1		2	
Stage	Initial decision	Construction	Operation (expansion) * Option of expansion decision at Year 10		

Figure 4-6: Structure of decisions for two phases

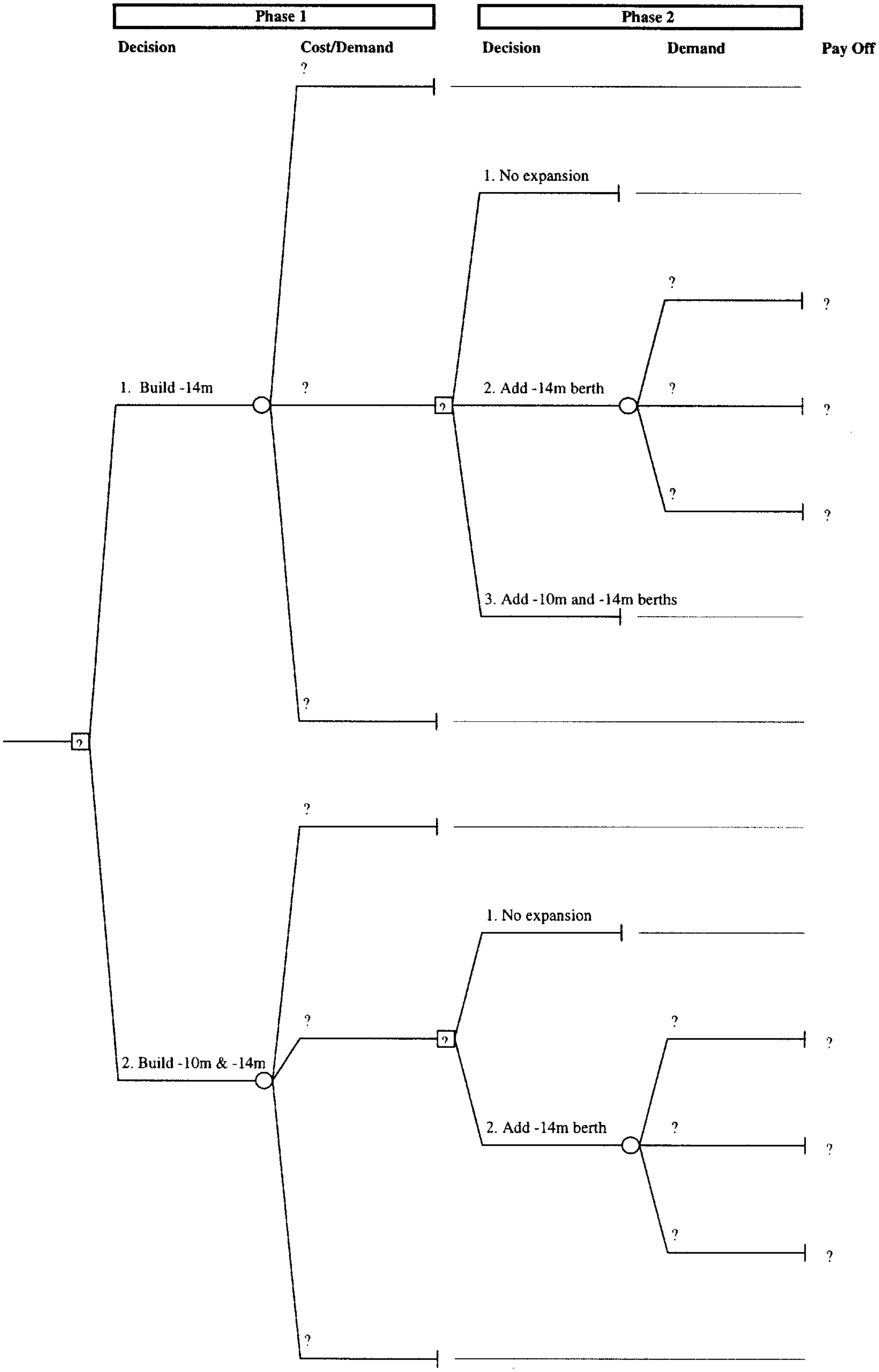


Table 4-2: Summary of uncertainties for decision tree analysis

Type	Uncertainty	Case	%	Note
Market	Market Growth	High	8.3	annual growth rate
		Medium	5.9	
		Low	3.6	
Project	Construction Cost	High	129	of estimated cost
		Medium	108	
		Low	90	
	Port Share (base) (first 5-yr operation)	High	17.1	of potential hinterland
		Medium	7.1*	
		Low	3.0	
	Port Share (addition) (first 5-yr operation)	High	2.9	annual additional share to base share
		Medium	2.4	
		Low	1.9	

* The medium share here is different from the average in Table 4-1 because the distribution is assumed as being lognormal (Appendix 2-3).

The optional decision for Phase 2 maximizes the expected NPV given observations of construction cost and demand growth during Phase 1. For example, in the actual investment case (Choice 2), if construction cost is medium, the best choice for Phase 2 is just to keep operation (no expansion) when the demand is medium or low, and to add the other –14m berth when the demand is high (Figure 4-7). Then, the set of best Phase 2 decisions that gives maximum expected NPV, given each scenario, constitutes the total NPV of a decision for Phase 1. The decision that has the higher total NPV should be taken for Phase 1.

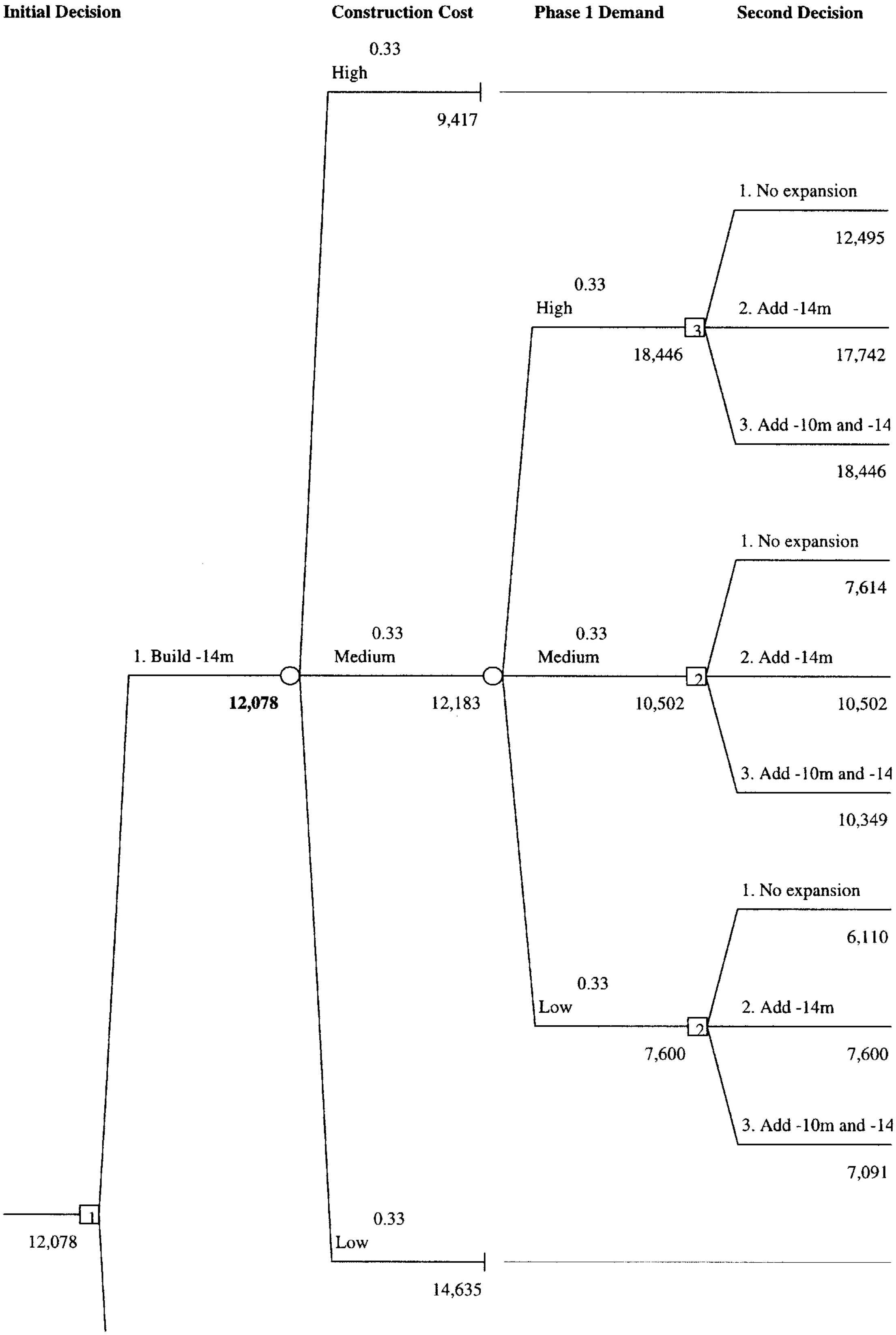
In this case study, while Choice 1 (Build –14m berth for Phase 1) gives the ***Total NPV of 12,078 million Yen***, Choice 2 (Build –10m berth and –14m berth for Phase 1) gives the ***Total NPV of 10,862 million Yen***. This implies that applying DSP to MOT's investment strategy, Choice 1 is the best and increases the ***NPV of 1,216 million Yen*** compared to Choice 2 if MOT's objective is to maximize the NPV of the project. The best choice for Phase 2 depends on outcomes of construction cost and demand growth during Phase 1. (Appendix 3 shows the entire result.)

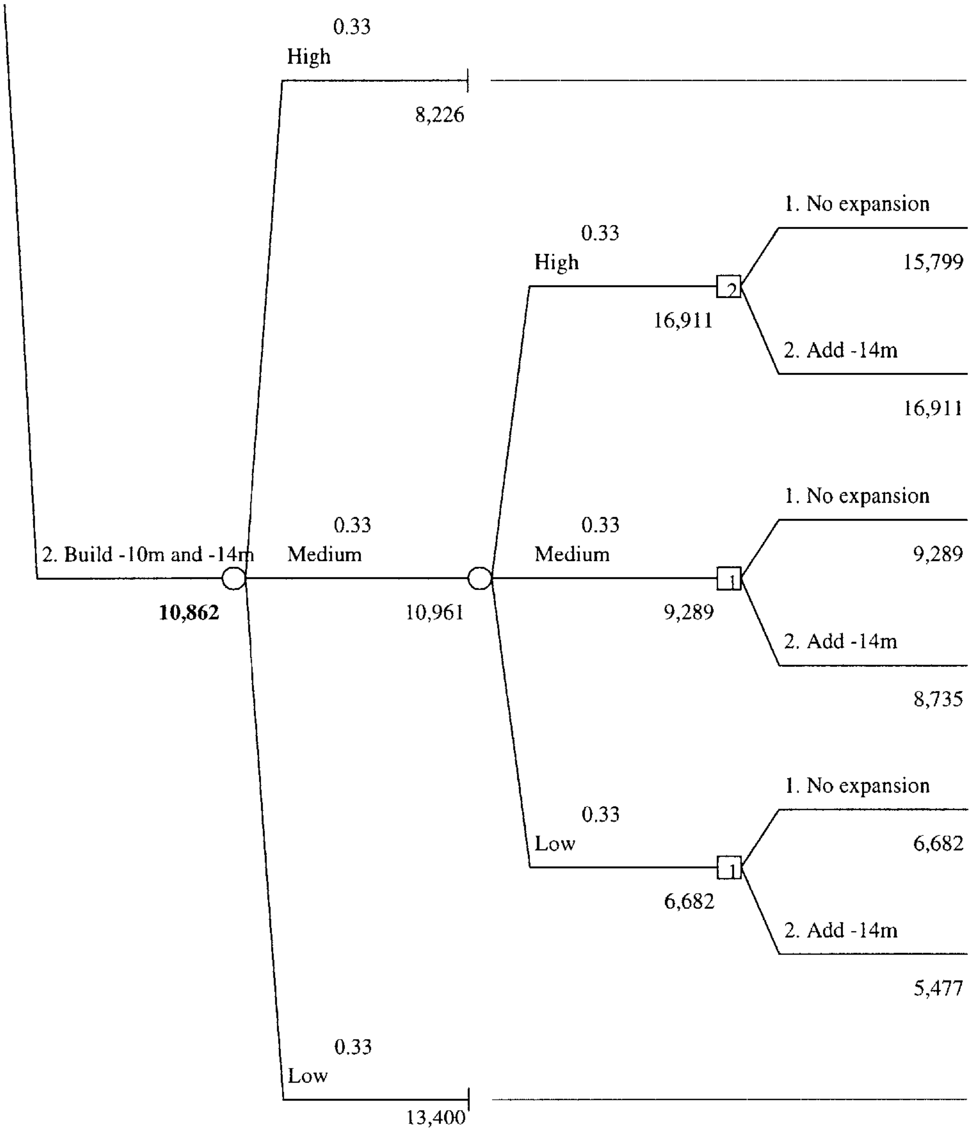
Step 4. Choose Real Options value calculator

Monte-Carlo simulation and Black-Scholes equation

Although the decision tree analysis illustrates the concept of DSP, it lacks the precision because of simplifications in creating discrete outcomes of uncertainties in this case study. For example, only three outcomes for demand uncertainties (high, medium, and low) are used throughout each Phase in this case. However, if there are three scenarios for a year, 3^{10} outcomes should arise for ten year period in reality. Also, the

Figure 4-7: Decision tree analysis (portion of result)




2. Build -10m and -14m
10,862
0.33
High
8,226
0.33
Medium
10,961
0.33
High
16,911
2
1. No expansion
15,799
2. Add -14m
16,911
0.33
Medium
9,289
1
1. No expansion
9,289
2. Add -14m
8,735
0.33
Low
6,682
1
1. No expansion
6,682
2. Add -14m
5,477
0.33
Low
13,400

assumption of lognormality on the distribution resulting from the convolution of market demand and project share is an approximation (Appendix 3).

The Monte-Carlo simulation fits this case study in valuing Real Options value. Because statistical references (mean, standard deviation, and distribution) of demand uncertainties are now determined, simulation overcomes the problems of decision tree analysis explained above.

Second, the Black-Scholes equation is also applicable to the calculation of the option value here because the expansion opportunity at Year 10 is seen as European call option as is the case with the Chapter 3 example.

Step 5. Calculate DSP-based NPV (with Real Options value)

Monte-Carlo simulation

Monte-Carlo simulation is applied to the determination of demand growth paths. First, using the statistical information defined above, ten realizations of demand growth paths are generated. The expected NPV of the ten realizations for the Phase 1 investment (either Choice 1 or Choice 2 without phase 2 expansion) gives a Base Expected NPV, which is defined in Chapter 3, for the Phase 1 facilities. Second, for each one of the ten realizations above, ten further realizations of demand paths are generated for the period after Year 11 (thus resulting in 100 realizations of project demand growth paths for the Phase 2 decision) (Appendix 4). Here, construction cost is dealt with as the three discrete variables defined above.

Option value is realized when the expected value of expansion, given information on Phase 1, is greater than the expected value of non-expansion. The option value arises by resolutions of demand uncertainty and cost uncertainty. (Because market demand uncertainty is never resolved, it has nothing to do with option value here. All option value coming from the resolution of demand uncertainty is attributed to the resolution of the project share uncertainty here.)

NPV with Real Options value (Total NPV)

- Choice 1: Building a -14m berth for Phase1 and exercise the suitable option when it is most advantageous for Phase 2 (Appendix 4: Table A4-2)

  Total NPV (13,199 million Yen) = Base Expected NPV (9,620 million Yen)

  + Option value (3,579 million Yen)

- Choice 2: Building a –10m berth and a -14m berth for Phase 1, and exercise the option when it is advantageous for Phase 2 (Appendix 4: Table A4-3)

  Total NPV (12,227 million Yen) = Base Expected NPV (12,017 million Yen)

  + Option value (210 million Yen)

Black-Scholes equation

Applying the same method explained in Chapter 3 to this case study, the Real Options value is obtained as follows (Appendix 5):

- Choice 1 (Appendix 5: Tables A5-2, and A5-4)

  Option Value = 4,378 million Yen

This value is similar to that of the Monte-Carlo simulation (3,579 million Yen) in terms of both absolute value and the percentage of the Base Expected value (45.5% vs. 37.2%).

- Choice 2 (Appendix 5: Table A5-6)

  Option Value = 61 million Yen

  Although this might seem to be very different from the Monte-Carlo outcome (210 million Yen), it is quite similar in terms of the percentage of the Base Expected value (0.5% vs. 1.7%).

Implications of the case study

Simple NPV vs. Base Expected NPV

The Base Expected NPV (the expected NPV of Phase 1 investment without Phase 2 investment) of Choice 2, 12,017 million Yen, is greater than its simple NPV, 10,185 million Yen. As mentioned in Chapter 3, this is not a universal property. If the deterministic scenario is very optimistic, the simple NPV can be greater than the Base Expected NPV. Even if a deterministic scenario is set for all medium cases, asymmetric outcomes can both increase and decrease the Base Expected NPV. This implies that, if MOT relies on the simple NPV valuation alone, the Ministry might make wrong decisions because the valuation is not correct even when option value is excluded. If uncertainties and risks are evaluated appropriately, the Base Expected NPV gives a more precise valuation.

Option Value and Total NPV

Although the option value in Choice 2 is very small, that in Choice 1 is significant. This implies that MOT might underestimate the project value in some cases if it does not value the Real Options of a project, which might result in failure to invest in a project that actually has a positive Total NPV (= Base Expected NPV + Option Value).

Second, the two methods of option calculation gave similar values in this case study. The Black-Scholes equation can be the quick solution, in particular, when the volatility of the present value of net benefit flow is known *a priori.*

DSP

It should be noted that the Total NPV of Choice 1 is greater than that of Choice 2 when the option value is taken into account. This happens because Choice 1 has higher flexibility than Choice 2 when significant uncertainties exist. This implies that the recognition of uncertainties and the incorporation of flexibility into projects can increase the total value of the projects. This conclusion is the same as that of decision tree analysis although there is minor difference in calculated NPVs.

When the objective of MOT is to maximize the NPV of the project, DSP suggests that MOT should invest in one berth at first, then add berths based on the outcomes of construction cost and demand.

What the Government Should Consider in Order to Effectively Use DSP

Applying DSP to the government's decision-making means change not only in valuation methodology but also in the government's rigid systems. In order to maximize the value of Real Options, the government should consider changing its perception with regard to master plans, five-year investment plans, and the regulation regarding subsidies.

Master Plans

Because it takes some time before a master plan is authorized under the current procedures set up by the national government, as Chapter 1 explains, a plan to be authorized should be regarded as a set of investment opportunities and be designed so as to ensure flexible expansions (or contraction, transfer use, closure) as much as possible. For example, as can be seen from the case study, having the plan of another –14m berth gives an additional option value to that of the actual investment. Additionally, it is important that the plan ensures the all the deployment strategies, such as those assumed in the case study.

It would also be worthwhile for the government to consider shortening the examination period required to authorize a plan. This would create the *de facto* effect of Real Options by increasing the flexibility of the authorized plan.

Investment Five-year Plans

Although most current investment five-year plans are not completely inflexible, it is difficult to initiate a project that has not been originally incorporated into the plan.

This is particularly true in the case of seaports and airports because the seaport and airport investment five-year plans designate individual seaports and airports to be funded during the five year period. If an investment five-year plan designates individual projects, it should not totally exclude other projects. It is beneficial for option values for the plan to include conditionally some projects that do not look very attractive at the time when the five-year plan is made. Furthermore, a five-year plan should not stick to initially included projects if they become unattractive as a result of changed circumstances.

Subsidies by the National Government

The Law Regarding Appropriate Enforcement of Subsidies, enacted in 1955, may be one of the major reasons why it is very difficult for local governments to abandon projects even when the investment appears to be unwise. According to this law, if local governments abandon the facilities developed using a subsidy, they have to return an amount equal to the subsidy to the national treasury, as Chapter 1 explains. Because the financial contribution of the national government to transportation infrastructure is usually large, the abandonment option is hardly available for local governments. Consequently, local governments tend to stick to original usage. Flexible employment of this act within an acceptable level would be helpful to increase the option value, and, in turn, the Total NPV of a project.

Conclusion of the case study (as answers to the questions presented in Introduction)

- The valuation method based on DSP works better than the system MOT currently uses in terms of the precision of valuation.
- DSP has advantages over the current system in terms of its ability to increase the real value of projects.
- Accordingly, it would be beneficial for the Japanese government to incorporate DSP into its transportation infrastructure investment.

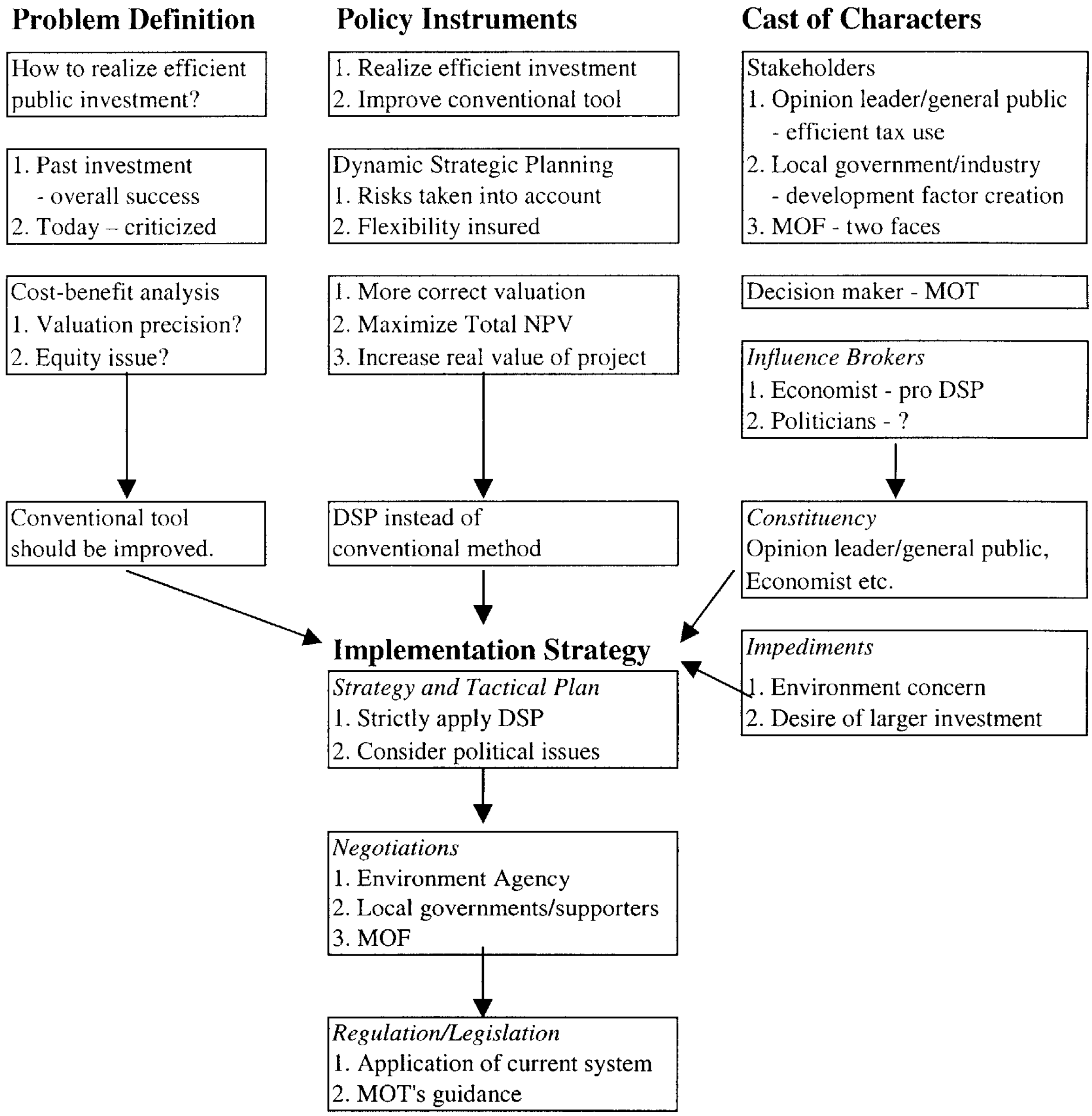
CHAPTER 5

POLICY ANALYSIS FOR IMPLEMENTATION OF DYNAMIC STRATEGIC PLANNING IN JAPAN'S MINISTRY OF TRANSPORTATION

Chapters 2, 3, and 4 show that there are uncertainties and risks in transportation infrastructure developments, which, if not taken into systematic consideration, might lead to unsound judgments. This would be particularly true if decision-makers relied on a single *a priori* deterministic scenario. Chapter 4 suggests that the government should use Total Net Present Value (TNPV), which includes option value, in evaluating projects. The valuation of TNPV not only implies that it is more correct than the simple NPV valuation, but also that the government can increase the value of its projects by applying DSP that takes into account uncertainties and risks and insures managerial flexibility.

This chapter analyzes policy issues in implementing Dynamic Strategic Planning (DSP). The application of DSP to projects has two expected results. First, the initiation of an investment that has almost zero NPV based on the conventional valuation becomes easier. Second, the initiation of a large-scale investment becomes more difficult. There are stakeholders who favor or oppose each result. In order to use the positive properties of DSP effectively while alleviating any negative impact on stakeholders, this chapter recommends that Japan's Ministry of Transportation (MOT) use DSP as a basis while the Ministry considers political issues (Figure 5-1).

Figure 5-1: Diagram of policy analysis for implementing Dynamic Strategic Planning in Japan's Ministry of Transportation



Problem definition: Conventional cost-benefit analysis alone cannot ensure optimal investment decision-making

As Chapter 1 indicates, investment by the Japanese government is required to be more efficient today than it used to be. For the past half-century, the Japanese government has almost continually invested in the nation's transportation infrastructure under the assumption that demand for it will increase rapidly. This situation, however, has changed. The economic growth of Japan in 1999 is not as strong as it used to be. The public sector is suffering from a huge budget deficit. Under such circumstances, some public works are being criticized as inefficient.

In March 1997, MOT announced that it would introduce cost-benefit analysis for its major new investments. The Ministry checks whether the Cost-Benefit Ratio of a major new project exceeds one and also evaluates the NPV of the project. While the incorporation of cost-benefit analysis into MOT's decision-making process represents progress, it could be dangerous if it is not used appropriately from a political perspective as well as from the standpoint of evaluation methodology.

First, in the real world in which there are many uncertainties and risks, cost-benefit analysis based on an *a priori* deterministic scenario can lead decision-makers to incorrect conclusions because this process does not reflect factors that significantly affect NPV. Also, current conventional cost-benefit analysis fails to capture the value of Real Options.

Second, if cost-benefit analysis were strictly applied to government's investment decision criteria, the results would be unfavorable to investments in the rural areas. The demand for transportation infrastructure in the countryside is less than that in metropolitan areas. For example, while the development of a container berth in the countryside costs almost same as it does in a metropolitan area, it does not accrue as much benefit. Accordingly, while it is often easy to see a Cost-Benefit Ratio of more than one in metropolitan areas, it is sometimes difficult to do so in a rural district. Nevertheless, from the point of view of distribution equity, which is one of government's most significant functions, this alone should not justify government investment in metropolitan areas to the exclusion of the countryside.

Thus, conventional cost-benefit analysis is not necessarily the best instrument to use as one of the criteria for determining investment. It needs to be improved.

Policy instruments: DSP

A desirable policy instrument alternative to conventional cost-benefit analysis must overcome its disadvantages. At the same time, it must, of course, ensure investment efficiency.

While it may be necessary to deal separately with the two fundamental efficiency and political issues identified above, DSP, which takes Real Options value into account, can deal with both. First, DSP-based valuation is more correct from the point of view of project valuation methodology, and decisions using DSP increase the efficiency of an investment. Investment efficiency should be the basis for any government decision on a project, even though this sometimes might be politically difficult. Otherwise, the government might just waste money even when using cost-benefit analysis is politically acceptable.

Second, as the case study shows, the TNPV including Real Options value using DSP is greater than the Base Expected NPV. This facilitates investment in the countryside. Here, it should be noted that it is important for the area to have a strategic development plan because this gives value to an expansion option.

This thesis, therefore, argues that DSP is the method that MOT should incorporate into its decision criteria for transportation infrastructure investment instead of conventional cost-benefit analysis.

Cast of characters: Stakeholders, decision-makers, and influence brokers

Before analyzing the cast of characters, the impact of the application of DSP to projects should be clear. It seems to have two major properties. First, the initiation of an investment that has almost zero NPV based on the conventional valuation becomes more feasible because DSP-based NPV captures the value of Real Options in projects. Second, the initiation of a large-scale investment might become more difficult because it might be risky when there are significant uncertainties in cost or demand.

Stakeholders

There are stakeholders who favor or oppose each property. Three major stakeholder groups can be identified: opinion leaders/the general public, local governments/industry, and an authority of financial appropriation (Table 5-1).

First of all, opinion leaders and the general public are concerned about the wasteful use of their taxes. In Japan, they are the fundamental driving force pressuring the national government to make its investments more efficient. Thus, they must be in favor of DSP because it ensures optimal tax use. (Attention, however, should be paid to the fact that the Environment Agency and other groups who are particularly conscious about the environment might not welcome the first property of DSP, the facilitation of investment.)

Second, because significant portions of the construction costs of major transportation infrastructure are borne by the national government in Japan, local governments, in particular those in countryside, are against the second property of DSP while they are in favor of the first. Public infrastructure is one of basic factors for a region to acquire competitive advantages over other regions [Porter 1990]. Thus, local governments may want a larger-scale infrastructure for the future development of the region. (This is also true for the national government to acquire competitive advantages over other nations.) The stake of industry may be the same as that of local government because it wants as many business opportunities as possible. These are political issues related to distribution equity.

Third, the financial authority, here the Ministry of Finance (MOF), has two faces. First, it is the ultimate entity responsible for the effective use of taxpayer's money. Particularly now that the Japanese government is suffering from a huge deficit, MOF is also the driver pressuring each branch of the government to reduce expenditures. In this sense, the position of MOF is the same as that of opinion leaders/the general public.

On the other hand, MOF is also concerned about overall economic conditions throughout Japan. Public works are sometimes used as a tool to stimulate economic activities mainly based on the Keynesian notion of effective demand [Blanchard 1997].

The private sector and its employees often welcome this policy. MOF sometimes must launch economic stimulus packages in spite of its responsibility to reduce the deficit. In this sense, the position of MOF is the same as that of local governments/industry.

Decision-makers

The decision-makers on this issue are MOT officials. Attention should be paid to the fact that MOT is not only the decision-maker, but also a stakeholder. Local governments, as well as branches of the national government, such as MOT and the Ministry of Construction (MOC), are the developers and supporters of public infrastructure projects. They usually try to obtain as large a budget as possible from the financial authorities, MOF. Complex mechanisms work behind this tendency. Under such circumstances, individual government sectors often work as delegates of different interest groups [Lowi 1979].

Influence brokers

Two major influence brokers are the economists and the politicians. Economists are supposed to support scientific decision-making by the government from the economics perspective. Accordingly, they should support DSP.

On the other hand, the positions of politicians are diverse. They represent various groups of stakeholders, and their influence as regional representatives seems to be quite strong. Consequently, they tend to be conscious of distribution equity, and may take the same position as that of local governments/industry.

Constituency and impediments

To sum up the above discussion, most stakeholders, except the environmentalists, generally favor the first property of the application of DSP. On the other hand, MOT must reconcile the conflicts arising from the second property.

Implementation strategy

Definition of Strategy and Tactical Plan

The key to the successful application of DSP is using its positive properties effectively, while alleviating any negative impact on stakeholders. The tactical plan to implement DSP has two steps. First, MOT should focus totally on DSP because its approach maximizes the NPV of a project and a DSP-based valuation is more correct than the conventional cost-benefit valuation is. This total focus of the DSP solves the problem of investment efficiency.

However, a second step is necessary because, if DSP is strictly applied to all projects, it becomes more difficult to initiate investment in a large-scale facility even when such an investment is politically desirable. To overcome this disadvantage of DSP, particularly to local governments/industry, and hence to MOT also, this thesis recommends that MOT allow a larger-scale investment if the investment has a positive NPV and is politically desirable. This possibility may solve the political issue.

Evaluation of Impediments

This section defines three alternative measures for making MOT's investment efficient for the purpose of comparison:

1. Simple NPV (current system): Investment decisions are made on the basis of a deterministic scenario.
2. Strict DSP: Investment decisions are made using only DSP so as to maximize the TNPV of a project.
3. Quasi DSP: Investment decisions are based initially on DSP. However, a larger-scale initial investment is also acceptable, as long as its TNPV is positive and its political implications are identified.

Table 5-2 evaluates reactions to the three alternative measures of each stakeholder group. First of all, for opinion leaders and the general public, each of the alternatives would be acceptable because all of them are designed to ensure investment efficiency. Alternative 1 might be less attractive because its valuation will be less correct than the others. Those who are particularly conscious about the environment might be unfavorable to Alternative 3. (This issue is discussed in the *Negotiations* section.)

Second, for local governments/industry, Alternative 1 is not attractive because it is inherently unfavorable to investments in the countryside. Although Alternative 2 saves projects whose NPVs are close to zero on the basis of Alternative 1, the smaller investment resulting from strict DSP is unattractive to local governments/industry. Alternative 3 can solve this problem for them.

Third, while the position of MOF depends on economic conditions in Japan, all alternatives are acceptable because they all ensure investment efficiency. (Alternative 1 might be less attractive because its valuation will be less correct than the others.)

Finally, the reaction of MOT as a stakeholder will be basically the same as those of local governments/industry now that all alternatives seek investment efficiency. MOT might prefer Alternative 1 because this measure is rather simple if the Ministry is able to set a deterministic scenario arbitrarily. However, MOT should notice that the more arbitrary the scenario is, the more difficult it is for MOT to justify it.

In sum, Alternative 3 is acceptable for all stakeholders because, even though quantified NPV is not necessarily maximized, it ensures the investment efficiency.

Negotiations

Significant negotiation counterparts are the Environment Agency, local governments and their supporters, and MOF. First, to deal with the concern about DSP's impact on the environment, cost-benefit analysis should be developed in conjunction with the Environment Agency. If NPV reflects the social cost and benefit including the environmental impact, the decision based on it should be rational for the Agency, too. (Transportation infrastructure investments often have positive environment effects.) It should also be noted that the current environmental assessment procedures in constructing major transportation infrastructure remain even if DSP is applied. Thus, the environmental protection groups can ensure the prevention of environmental deterioration.

Table 5-1: Stakeholders and their powers

Stakeholders	Powers	Initiatives
Opinion leader/ General public	Formation of public opinion	Pressuring governments
Environment authorities	Authorizing environment assessment	Environment protection activities
Local government/ Industry	Governing citizens	Demanding budget (by way of politicians, sometimes)
Ministry of Finance	Budget allocation/ appropriation	Pressuring each branch
Ministry of Transportation	Making decision	Policy implementation

Table 5-2: Stakeholders and their reactions to alternative measures

Stakeholders	Reactions		
	Alternative 1: Simple NPV	Alternative 2: Strict DSP use	Alternative 3: Quasi DSP
Opinion leader/ General public	Welcome (Could be less attractive)	1. Attractive 2. Attractive	Acceptable
Environment authorities	(Acceptable)	(1. Unattractive) (2. Attractive)	Acceptable
Local government/ Industry	Not welcome	1. Attractive 2. Unattractive	Attractive
Ministry of Finance	(Could be less attractive)	Depends	(Attractive)
Ministry of Transportation	Depends (Could be attractive)	1. Attractive 2. Unattractive	Attractive

1. Initial investment is facilitated.
2. Initial investment becomes smaller.

Second, to deal with the political issue resulting from DSP (the second property), the standard of the circumstances under which a larger-scale investment is allowed should be set in conjunction with local governments and their supporters (politicians etc.). The threshold for investment in rural areas should be lowered. Also, discussing the method of weighting benefits in the countryside with the local governments and related stakeholders may be useful.

Third, because MOF is the ultimate authority in authorizing the budget of development, negotiations above should be proceeded in conjunction with MOF.

Regulation/Legislation

The advantage of this proposal is that the incorporation of (quasi) DSP is the application of the current systems; thus no special legislation is required. The decision as to whether to use it would be made internally by MOT. From the perspective of accountability to the public regarding this policy, MOT should be the agency responsible for guidance in implementing (quasi) DSP.

CONCLUSION

This thesis shows that it is beneficial for the Japan's Ministry of Transportation (MOT) to incorporate Dynamic Strategic Planning (DSP) into its decision-making in investing transportation infrastructure projects. A case study of a container terminal development in Japan demonstrates that the project valuation based on DSP is more precise than the conventional method and that DSP has advantages over the conventional method in terms of its ability to increase the real value of projects.

Chapter 1 first introduces criticisms of inefficient infrastructure investments in Japan both at macro and project levels. It then overviews Japanese transportation infrastructure development systems that might affect investment efficiency, such as inflexible investment five-year plans, and so on. This chapter finally introduces efforts towards more efficient investments, such as the incorporation of cost-benefit analysis into investment decision criteria.

Chapter 2 first demonstrates that forecasts are never perfect in the real world. It then introduces uncertainties and risks faced by the transportation infrastructure using a dichotomy: market uncertainties and project uncertainties.

Chapter 3 presents the concept and advantages of DSP using the example of an airport investment. This arbitrarily created simple example explains the concept of DSP and the fact that it takes into account future uncertainties and risks and insures managerial flexibility. It also explains advantages of DSP as well as the defects of Net Present Value (NPV) based on a deterministic scenario (the simple NPV based on conventional cost-benefit analysis). This chapter finally introduces major methods to include projects' Real Options value: decision tree analysis, the Black-Scholes equation, and Monte-Carlo simulation.

Chapter 4 is dedicated to a case study in which a container terminal development in Japan is evaluated by proposing the DSP approach based on the cost-benefit analysis framework. The case study demonstrates that the project valuation based on DSP using decision tree analysis, the Black-Scholes equation, or Monte-Carlo simulation, is more precise than the conventional method. This chapter also explains that DSP has advantages over the conventional method in terms of its ability to increase the real value of projects.

Chapter 5 analyzes policy issues in implementing DSP. There are two properties of the application of DSP to projects. First, the initiation of investment that has almost zero NPV based on the conventional valuation becomes easier. Second, the initiation of large-scale investment becomes more difficult. There are stakeholders who favor or oppose each property. In order to use preferable properties of DSP effectively while alleviating negative impacts on stakeholders, this chapter recommends that MOT use quasi DSP considering political issues.

It is beneficial for Japan's MOT to incorporate DSP into its decision criteria in investing transportation infrastructure projects instead of conventional cost-benefit analysis, thus the thesis recommends that MOT use DSP as a basis for project evaluation.

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Appendix 1: Cost-Benefit Model

1. Global variables

(1) Discount Rate (for the simple NPV and decision analysis): 4% (the rate that MOT applies based on several interest rates in public loan).

(2) Capacity of each berth: -10m = 600,000 ton/year, -14m = 1,000,000 ton/year (Because there is no official standard regarding this in Japan, they are assumed as being two-thirds of the average ton/(berth length) in the port of Kobe, the largest port in Japan, in 1994 (before the earthquake). Two-thirds is the ratio of the number of cranes per total berth lengths in Port A to that in the port of Kobe.)

2. Cost Model

(1) Construction Cost: This is basically based on actual data obtained from the port authority of Port A. Common costs are allocated to each berth using the ratio of berth lengths (-10m berth = 170m, -14m berth = 280m). However, as each berth has a same type of crane, the crane costs are allocated equally. Construction cost and period of undeveloped –14m berth are assumed as being the same as those of the developed –14m berth.

(2) Operation Cost: $Y\ (1{,}000\ \text{Yen}) = 176{,}705 * X\ (1{,}000\ \text{ton})^{0.32895726}$.

This formula is created here so as to reflect the economy of scale in terminal operation. The coefficients are determined by regression using data on container volume and operation cost obtained from a major terminal operating company in Japan ($R^2 = 0.50$).

Table A1-1: Container Terminal Operation Cost

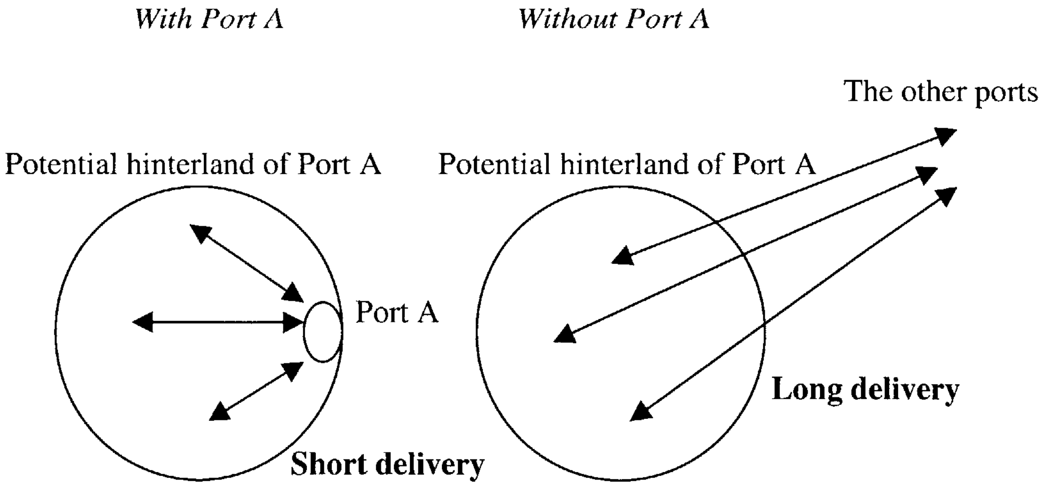
Year	Container Handling (1,000 ton)	Operation cost (1,000 Yen)
1	21,761	4,562,471
2	22,532	4,915,588
3	28,539	5,004,529
4	25,321	4,912,941
5	26,334	5,271,353

Note: Data are acquired on anonymous basis from a terminal operation company in Japan. Operation cost here is assumed as being the total expense of the company multiplied by the ratio of the number of container terminals to total the company operates.

3. Benefit Model

(1) Framework of Benefit Model

Figure A1-1: Framework of Benefit Model



➔ Savings of transportation costs (including time value of cargoes) for the potential hinterland of Port A represent the benefit of developing Port A. (No induced cargo demand because of the development of Port A is assumed, i.e., there is no demand curve transition in the case with Port A with respect to the case without Port A.)

(2) Potential hinterland of Port A: The area where Port A is most advantageous for users in terms of access cost and time (The prefecture B).

(3) Alternative ports without Port A: The shares of each port that handled cargoes originated in and destined for the prefecture B in 1993 are assumed to be constant for the future if Port A had not been developed. (Four major port areas handled the container cargoes originated in and destined for the prefecture B.) [Japan, Ministry of Transportation, 1994]

(4) Transportation cost: The transportation route between the prefecture B and each port area is assumed as the shortest route in terms of time. Then, transportation cost is calculated based on tariff data [Kotsu Nihon Sha 1997 and Zenkoku Kosoku Doro Kensetsu Kyogikai 1998]. One TEU (Twenty-feet-container Equivalent Unit) is converted into 18.7 ton based on an interview to Japan's Ministry of Transportation (MOT) [1999b].

(5) Transportation time value: The average speeds on roads are assumed as the average of overall Japan based on data in *Road Transportation Census*, [Japan, Ministry of

Construction 1995]. Time value of container cargoes is based on an interview to MOT [1999b].

(6) Salvage Value: Salvage value of the terminal should be added at the end of the final year of the valuation period. Among the facilities developed, the value of land, crane, and warehouse are taken into account because they are likely to have market value if the operation of Port A is abandoned. (Berth and anchorage are not likely to have market value when the project is abandoned because they are very specific in terms of both objective and location.)

- Land: Development cost is used as the salvage value. Although the salvage value of land should be the market value if it is sold, the development cost is assumed as being a good approximation because sufficient information on its future market value is not available.
- Crane: The formula, $P = 0.9 * C *(1 - t/17)$, is applied to its salvage value (P = salvage value; C = development cost; t = duration of usage; 17 = the depreciation period of a crane [Japan, Ministry of Finance 1995a and 1995b]). The salvage value after 17 years ($0.1* C$) is assumed to be canceled off with its removal cost.
- Warehouse: The same valuation as crane is applied except that warehouse has 45 years of depreciation periods instead of 17years [Japan, Ministry of Finance 1995a and 1995b].

Table A1-2: Global Variables for simple NPV calculation

▨ indicates input data
(The other cells are calculated.)

Discount rate	4%

Capacity (1,000 ton/yr)

-10m Berth	600
-14m Berth	1,000

National market growth rate		5.9%

Share in hinterland

1st 5yr of operation (yr 6-10)	7.1%
After yr 10 (increase %/yr)	2.4%

Potential hinterland demand at yr 0 (1,000 ton)	482

Potential hinterland demand

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Demand (1,000 ton)	510	541	572	606	642	680	720	762	807	855	906	959	1016	1075	1139	1206	1277	1353	1432	1517
Year	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35					
Demand (1,000 ton)	1606	1701	1802	1908	2020	2140	2266	2400	2541	2691	2850	3018	3196	3385	3584					

Deterministic Demand Scenario

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Demand (1,000 ton)	-	-	-	-	-	49	51	54	58	61	86	114	146	180	218	260	306	356	412	472
Year	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35					
Demand (1,000 ton)	539	611	691	777	872	974	1086	1208	1340	1484	1640	1809	1992	2191	2406					

Table A1-3: Cost Model

Construction (1,000 Yen)

Year	1	2	3	4	5	Total
-10m Berth	34,475	749,600	701,375	1,731,675	1,362,625	4,579,750
Berth	*26,600*	*453,000*	*384,000*	*121,200*	*70,000*	*1,054,800*
Anchorage		*145,600*	*67,000*	*2,100*		*214,700*
Allocation	7,875	151,000	250,375	1,608,375	1,292,625	3,310,250
Land	7,875	139,500	102,375	795,375	562,500	1,607,625
Crane		11,500	148,000	813,000	220,500	1,193,000
Warehouse					59,625	59,625
Miscellaneous					450,000	450,000
-14m Berth	82,125	1,185,600	1,804,325	3,926,625	2,859,575	9,858,250
Berth	*69,000*	*862,000*	*805,900*	*449,600*	*183,000*	*2,369,500*
Anchorage		*79,600*	*679,800*	*1,338,400*	*669,200*	*2,767,000*
Allocation	13,125	244,000	318,625	2,138,625	2,007,375	4,721,750
Land	13,125	232,500	170,625	1,325,625	937,500	2,679,375
Crane		11,500	148,000	813,000	220,500	1,193,000
Warehouse					99,375	99,375
Miscellaneous					750,000	750,000
Total	*116,600*	*1,935,200*	*2,505,700*	*5,658,300*	*4,222,200*	*14,438,000*

-10m, -14m Common (Before Allocation)

Land	*21,000*	*372,000*	*273,000*	*2,121,000*	*1,500,000*	*4,287,000*
Crane		*23,000*	*296,000*	*1,626,000*	*441,000*	*2,386,000*
Warehouse					*159,000*	*159,000*
Miscellaneous					*1,200,000*	*1,200,000*
Subtotal	*21,000*	*395,000*	*569,000*	*3,747,000*	*3,300,000*	*8,032,000*

Total	*116,600*	*1,935,200*	*2,505,700*	*5,658,300*	*4,222,200*	*14,438,000*

Italic: Original Data

Regular: Assumption

Operation Cost (1,000 Yen) =	176,705	*	(1,000 ton) ^	0.3289573

Table A1-4: Benefit Model

1 TEU (t)	18.7

HWY speed (km/h)	66.5
Standard road speed (km/h)	33.5

Time Value (Y1000/TEU/h)	1.5

Without Port A

Handling Port Area	Distance (km)	HWY (km)	Standard Road (km)	Tariff (Y1000/TEU)	Toll (Y1000/TEU)	Cost (Y1000/ton)	TR time (h)	Time Value (Y1000/t)
B	197	18	179	80.1	1.37	4.36	5.61	0.45
C	700	563	137	165.39	38.24	10.89	12.56	1.01
D	895	751	144	192	50.96	12.99	15.59	1.25
E	1,240	1,077	163	238.55	73.01	16.66	21.06	1.69

Handling Port Area	Handling (t/mon.)	Share(%)	Cost (Y1000/t)	Time Value (Y1000/t)
B	25,969	71.57%	3.118141982	0.322307955
C	9,645	26.58%	2.894627561	0.267725807
D	32	0.09%	0.011458593	0.001103039
E	637	1.76%	0.292506154	0.029659798
Total	36,283	100.00%	6.31673429	0.6207966

With Port A

Handling Port	Distance (km)	HWY (km)	Standard Road (km)	Tariff (Y1000/TEU)	Toll (Y1000/TEU)	Cost (Y1000/t)	TR time (h)	Time Value (Y1000/t)
A	21	18	3	24.58	1.37	1.39	0.36	0.03

Net Saving

Cost (Y1000/t)	4.93
Time Value (Y1000/t)	0.59

Salvage Value (Depreciation Method)

	Salvage Value ratio	Period (yr)
Land	1	N.A.
Crane	0.1	17
Warehouse	0.1	45

Table A1-5: Actual Investment (Start building -10m & -14m Berths at year 1, and no additional investment.)

Discount rate	4%
Demand Scenario	Deterministic
NPV at the year 0 (1,000 Yen)	10,185,422

Unit: 1,000 Yen

Year	1	2	3	4	5	6	7	8	9	10	11	12
Cost component												
Construction cost	116,600	1,935,200	2,505,700	5,658,300	4,222,200							
Operation cost						633,595	645,656	657,947	670,472	683,235	765,921	840,325
Total Cost	116,600	1,935,200	2,505,700	5,658,300	4,222,200	633,595	645,656	657,947	670,472	683,235	765,921	840,325
Benefit component												
TR cost saving						239,109	253,216	268,156	283,977	300,732	425,599	564,153
Time saving						28,713	30,407	32,201	34,100	36,112	51,107	67,744
Salvage value												
Land												
Crane												
Warehouse												
Total Benefit	0	0	0	0	0	267,821	283,623	300,357	318,078	336,844	476,705	631,898
Net Benefit	-116,600	-1,935,200	-2,505,700	-5,658,300	-4,222,200	-365,773	-362,033	-357,591	-352,394	-346,391	-289,216	-208,427
PV of Net Benefit	-112,115	-1,789,201	-2,227,558	-4,836,739	-3,470,341	-289,076	-275,116	-261,288	-247,588	-234,010	-187,869	-130,183
Cumulative PV	-112,115	-1,901,317	-4,128,875	-8,965,613	-12,435,954	-12,725,030	-13,000,145	-13,261,433	-13,509,021	-13,743,031	-13,930,900	-14,061,083

Year	13	14	15	16	17	18	19	20	21	22	23	24
Cost component												
Construction cost							23,000	296,000	1,626,000	441,000		
Operation cost	909,523	975,256	1,038,614	1,100,335	1,160,940	1,220,819	1,280,268	1,339,525	1,398,779	1,458,189	1,517,889	1,577,993
Total Cost	909,523	975,256	1,038,614	1,100,335	1,160,940	1,220,819	1,303,268	1,635,525	3,024,779	1,899,189	1,517,889	1,577,993
Benefit component												
TR cost saving	717,576	887,138	1,074,212	1,280,271	1,506,906	1,755,828	2,028,877	2,328,033	2,655,427	3,013,350	3,404,265	3,830,818
Time saving	86,168	106,529	128,993	153,737	180,952	210,843	243,631	279,554	318,868	361,848	408,790	460,011
Salvage value												
Land												
Crane												
Warehouse												
Total Benefit	803,744	993,668	1,203,205	1,434,008	1,687,858	1,966,670	2,272,507	2,607,587	2,974,296	3,375,199	3,813,055	4,290,829
Net Benefit	-105,780	18,412	164,590	333,673	526,918	745,852	969,239	972,062	-50,484	1,476,009	2,295,166	2,712,836
PV of Net Benefit	-63,528	10,632	91,391	178,151	270,506	368,173	460,042	443,636	-22,154	622,810	931,209	1,058,335
Cumulative PV	-14,124,611	-14,113,979	-14,022,588	-13,844,437	-13,573,931	-13,205,758	-12,745,716	-12,302,079	-12,324,233	-11,701,423	-10,770,214	-9,711,879

Year	25	26	27	28	29	30	31	32	33	34	35
Cost component											
Construction cost											
Operation cost	1,638,601	1,699,803	1,761,678	1,824,298	1,887,730	1,952,036	2,001,089	2,001,089	2,001,089	2,001,089	2,001,089
Total Cost	1,638,601	1,699,803	1,761,678	1,824,298	1,887,730	1,952,036	2,001,089	2,001,089	2,001,089	2,001,089	2,001,089
Benefit component											
TR cost saving	4,295,854	4,802,429	5,353,826	5,953,570	6,605,448	7,313,523	7,886,651	7,886,651	7,886,651	7,886,651	7,886,651
Time saving	515,853	576,684	642,896	714,914	793,193	878,220	947,042	947,042	947,042	947,042	947,042
Salvage value											4,839,971
Land											4,287,000
Crane											505,271
Warehouse											47,700
Total Benefit	4,811,707	5,379,112	5,996,722	6,668,485	7,398,641	8,191,743	8,833,693	8,833,693	8,833,693	8,833,693	13,673,663
Net Benefit	3,173,106	3,679,309	4,235,044	4,844,187	5,510,911	6,239,707	6,832,604	6,832,604	6,832,604	6,832,604	11,672,574
PV of Net Benefit	1,190,285	1,327,087	1,468,783	1,615,427	1,767,081	1,923,818	2,025,595	1,947,688	1,872,777	1,800,747	2,958,011
Cumulative PV	-8,521,593	-7,194,506	-5,725,723	-4,110,295	-2,343,214	-419,396	1,606,200	3,553,888	5,426,664	7,227,411	10,185,422

Appendix 2: Statistics Regarding Uncertainties

1. Construction costs

Using data shown in Table 2-7 and assuming that the ratio of actual to estimated cost is lognormally distributed, the Bracket-Median method gives three discrete percentages of actual cost to estimated cost with equal probability as follows [Neely 1998]. (The original data obtained are assumed as being for a medium-cost case.)

Table A2-1: Actual and Estimated Cost of Container Terminal Construction in Japan and its distribution (Cost Unit: 10^8 Yen)

Seaport	Terminal	A. Actual	B. Estimate	C. A/B(%) ~ LND	D. ln(C) ~ ND
Y	1	142	149	95	4.55
	2	136	150	91	4.51
K	1	170	147	116	4.75
	2	243	179	136	4.91

Source: Japan, Ministry of Transportation (1999a)

Note: LND = Lognormal distribution; ND = Normal distribution

Statistics about associated ND	D
Mean (μ)	4.68
Standard Deviation (σ)	0.19

Table A2-2: Three discrete costs by the Bracket-Median method

Case	Probability	D	C. exp(D) (%)	Note
High	0.33	4.86	129	$D = \mu + 0.975*\sigma$
Medium	0.33	4.68	108	$D = \mu$
Low	0.33	4.50	90	$D = \mu - 0.975*\sigma$

2. Market demand

The latest ten year data on container cargo throughout Japan show an average annual growth rate of 5.9% with the standard deviation of 2.4%/year growth rate. Assuming that the ratio of the annual growth rate is normally distributed, the Bracket-Median method gives three discrete annual growth rates as follows.

Table A2-3: National container cargo volume

Year	10,000 ton	ratio ~ ND
1988	9,993	
1989	10,731	1.074
1990	11,528	1.074
1991	12,493	1.084
1992	12,974	1.039
1993	13,480	1.039
1994	14,747	1.094
1995	15,597	1.058
1996	16,468	1.056
1997	16,798	1.020

Source: Nihon Kowan Kyokai (1998)

'88-'97 annual growth rate (μ)	1.059

Standard deviation of ratio (σ)	0.024

Table A2-4: Three discrete market growths by the Bracket-Median method

Case	Probability	Annual growth rate (R)	Note
High	0.33	1.083	$R = \mu + 0.975*\sigma$
Medium	0.33	1.059	$R = \mu$
Low	0.33	1.036	$R = \mu - 0.975*\sigma$

3. Project share

(1) Base share (first five years of operation)

N seaport and H seaport, which are similar to A seaport in terms of scales of seaport facilities and hinterland population, are analyzed. During the first five years of container-handling, the average share captured by each seaport in each potential hinterland does not show a strong time-series tendency. (R^2 of simple time series regression (Share = a + b* Year) is only 0.17, and t-statistic of the coefficient for the variable Year, b, is only 0.78.) Assuming that the share acquired by seaport A for the first five years of operation is just lognormally distributed, data on seaports N and H give –2.64 on average with 0.9 standard deviation for the associated normal distribution base. Three discrete shares are given by the Bracket-Median method.

It should be noted that there is no data as to time-series data for the share of each seaport in its hinterland actually. Share in each year is calculated assuming that each seaport's hinterland is the prefecture at which it is located and the share of each prefecture's cargo to the nation is the same as data in 1994

Table A2-5: Project share during the first five years of operation

Year	Average	Port N ~ LND	Port H ~ LND	Ln(N) ~ ND	ln(H) ~ ND
1	0.092	0.024	0.159	-3.72	-1.84
2	0.107	0.024	0.190	-3.74	-1.66
3	0.085	0.032	0.138	-3.44	-1.98
4	0.085	0.041	0.130	-3.20	-2.04
5	0.124	0.041	0.208	-3.21	-1.57

Source: Japan, Ministry of Transportation (1994 and 1999a)
Note: LND = Lognormal distribution; ND = Normal distribution

Statistics	Share	ln(Share)
Mean (μ)	0.099	-2.64
Standard Deviation (σ)	0.074	0.89

Table A2-6: Three discrete shares (first 5-yr. operations) by the Bracket-Median method

Case	Probability	Share	ln(Share)	Note
High	0.33	0.171	-1.77	ln(Share) = μ+ 0.975*σ
Medium	0.33	0.071	-2.64	ln(Share) = μ
Low	0.33	0.030	-3.51	ln(Share) = μ- 0.975*σ

(2) Annual incremental share (after five years of operation)

After five years of operation, the average share captured by each seaport in each potential hinterland shows an incremental time-series tendency starting from the base share, the first five year average (9.9%). R^2 of simple time series regression (Share = 0.99 + 0.024* Year) is 0.81, and t-statistic of the coefficient for the variable Year, 0.024 is 12. Thus, the share captured by seaport A is expected to increase by 2.4%/year on average after the first five years of operation.

The same time-series regression on seaport N gives the coefficient of 0.028 for the variable Year, while that on seaport H gives 0.020. These two data of seaport N and seaport H constitute 0.005 standard deviation of the annual incremental share. Three discrete shares are given by the Bracket-Median method.

Table A2-7: Project share after the first five years of operation

Year	Average	Port N	Port H
5 yr. average	0.099	0.032	0.165
6	0.158	0.038	0.279
7	0.140	0.052	0.227
8	0.157	0.113	0.200
9	0.181	0.152	0.210
10	0.222	0.202	0.241
11	0.253	0.181	0.324

Source: Japan, Ministry of Transportation (1994 and 1999a)

Table A2-8: Annual additional share after the first five years of operation (~ ND)

Year	N seaport	H seaport
After 5 yr.	0.028	0.020

Mean (μ)	0.024
Standard Deviation (σ)	0.005

Table A2-9: Three discrete additional shares (after 5-yr. operations) by the Bracket-Median method

Case	Probability	Additional share(%/yr.)	Note
High	0.33	0.029	Increase = $\mu + 0.975*\sigma$
Medium	0.33	0.024	Increase = μ
Low	0.33	0.019	Increase = $\mu - 0.975*\sigma$

Appendix 3: Decision Tree Analysis for Case Study

1. Demand scenario during the first five years of operation

Using the results shown in Appendix 2, three discrete outcomes of market growth rates (high: 8.3%/yr; medium: 5.9%/yr; low: 3.6%/yr) and three discrete outcomes of base project shares (high: 17.1%; medium: 7.1%; low: 3.0%) yield nine demand growth paths. Assuming that the distribution of nine demands for each year is lognormally distributed, the Bracket-Median method gives three discrete demands for each year. Thus, three demand growth paths for the first five years of operation are defined (H1, M1, L1) so that the Excel treeplan can be used.

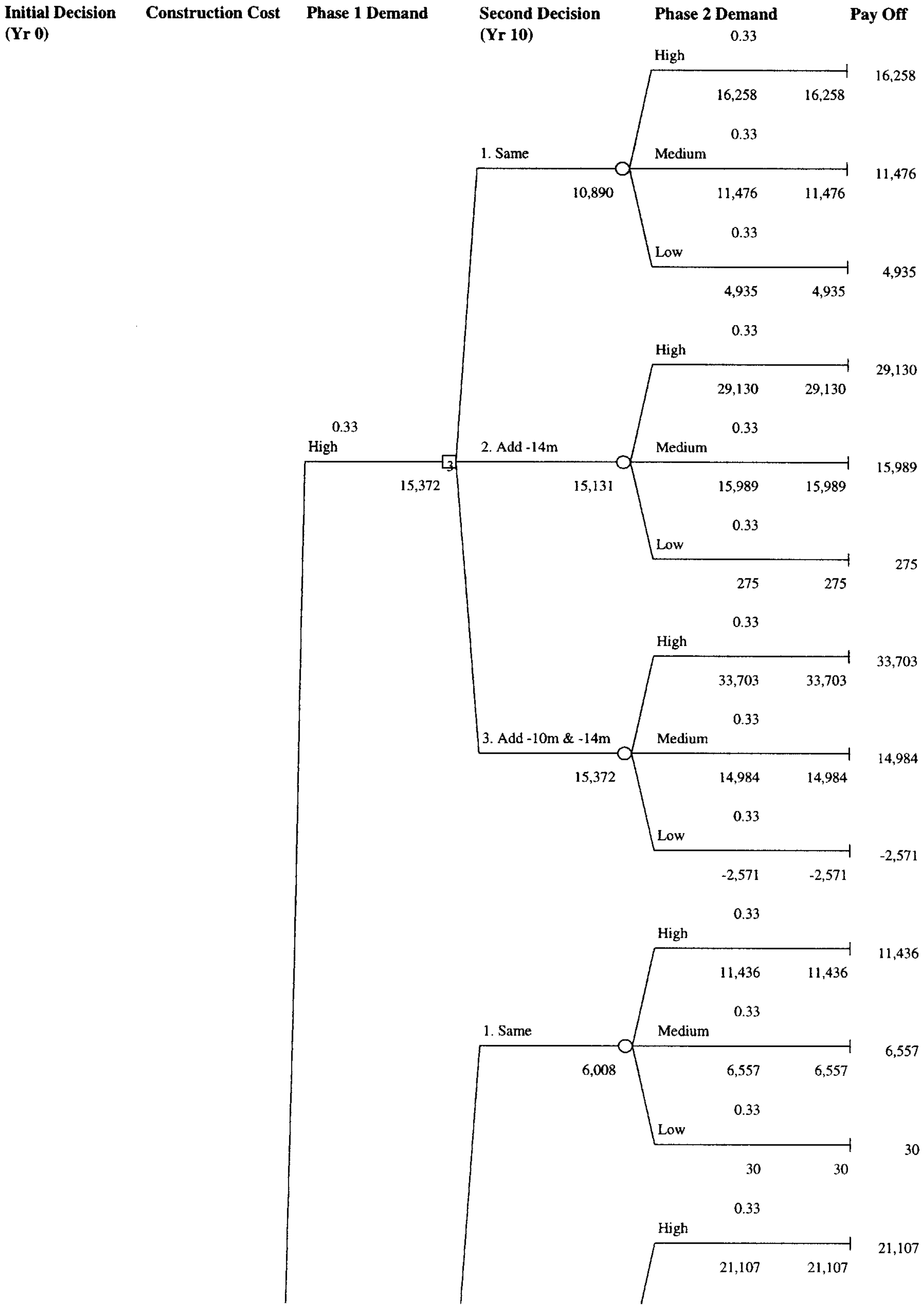
2. Demand scenario after the first five years of operation

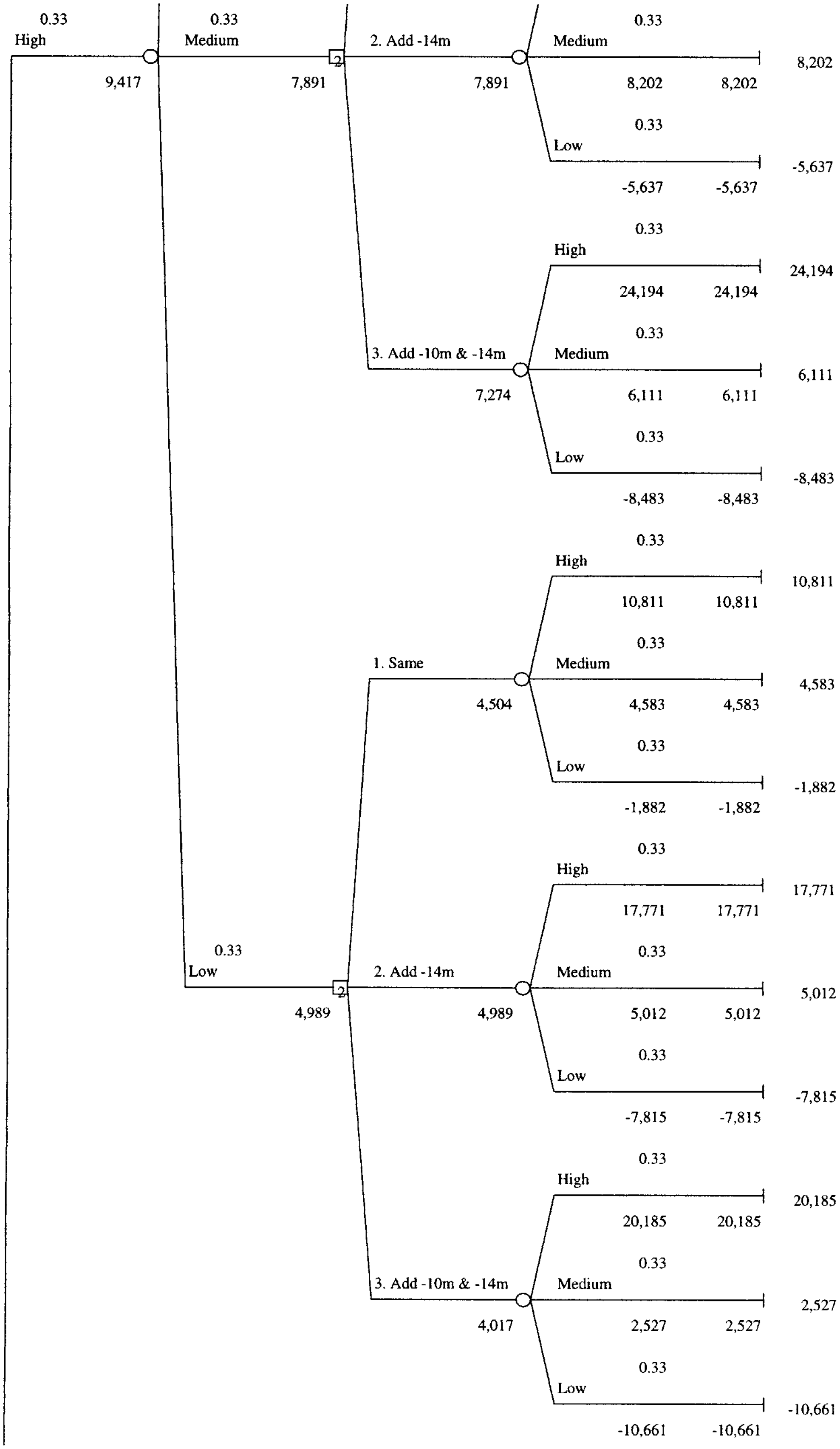
For each one of three demand growth paths in the first five years of operation (H1, M1, L1), the same procedure as described above is used in order to obtain three demand growth paths for the period after the first five years of operation. As a result, nine demand growth paths are used in the decision tree analysis (H1H2, H1M2, H1L2; M1H2', M1M2', M1L2'; L1H2", L1M2", L1L2").

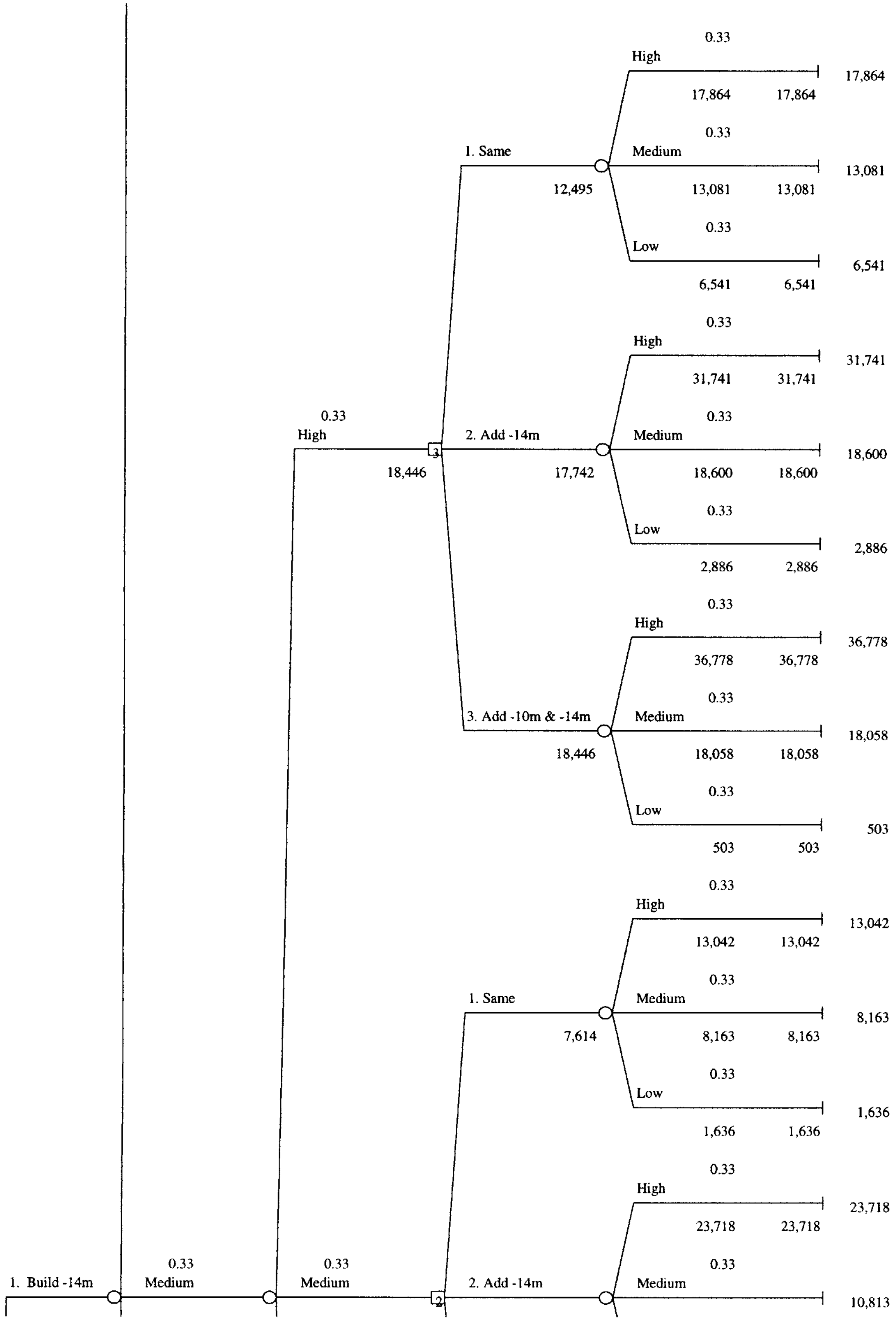
Table A3-1: Nine demand growth paths

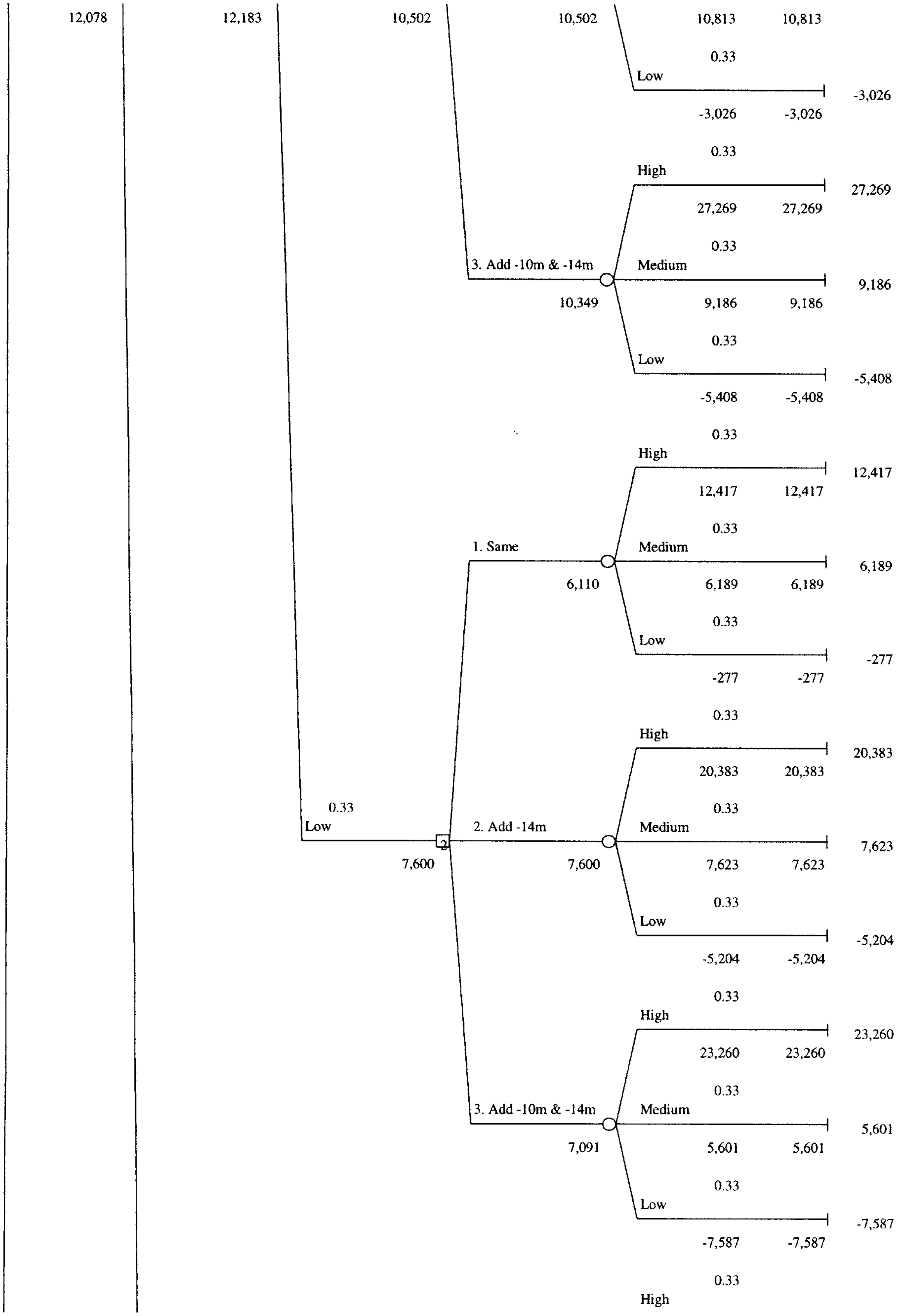
First 5 yrs. of operation	After 5 yrs. of operation
H1	H2
	M2
	L2
M1	H2'
	M2'
	L2'
L1	H2"
	M2"
	L2"

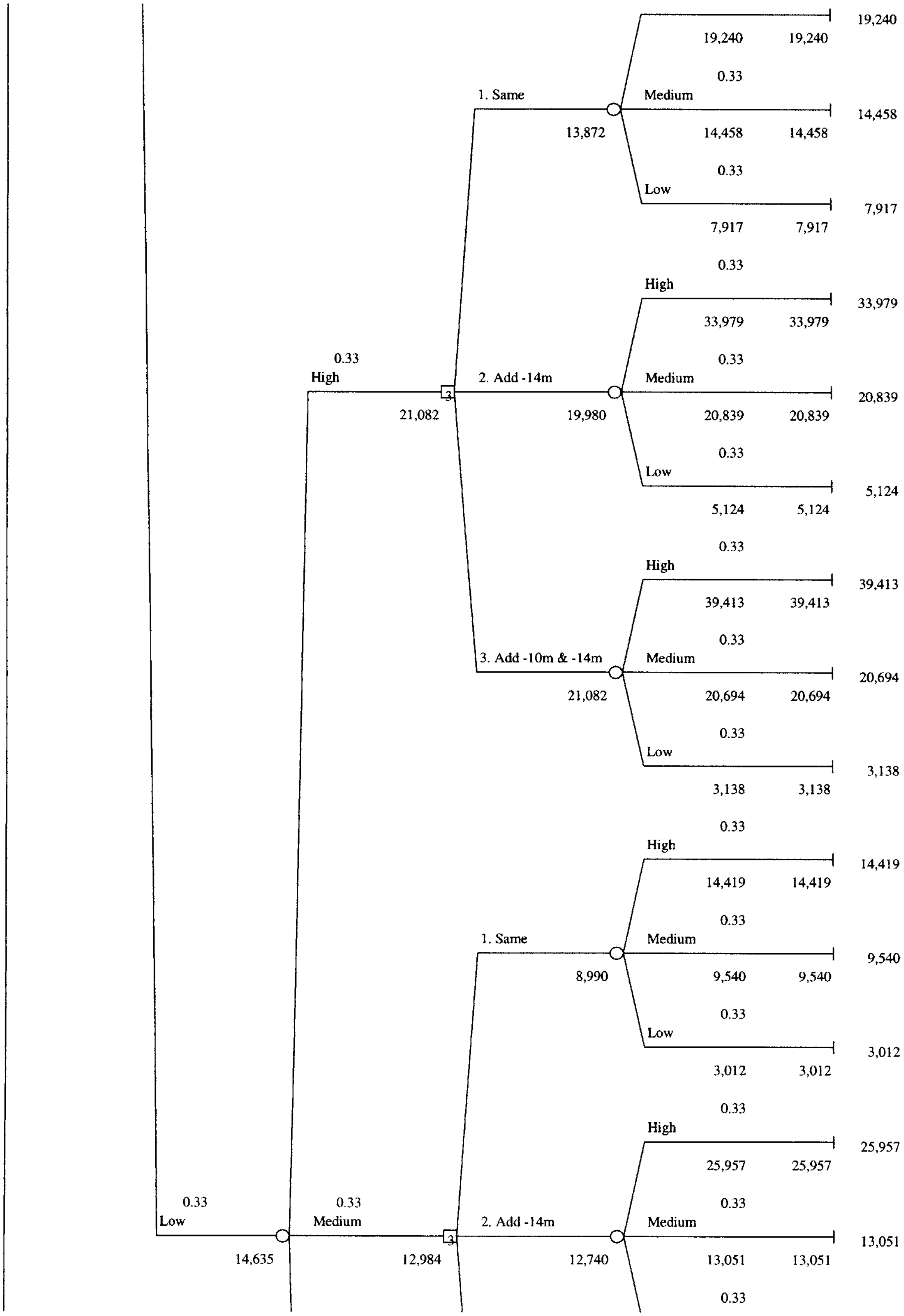
Figure A3-1: Decision tree for case study (NPV Unit: million Yen)

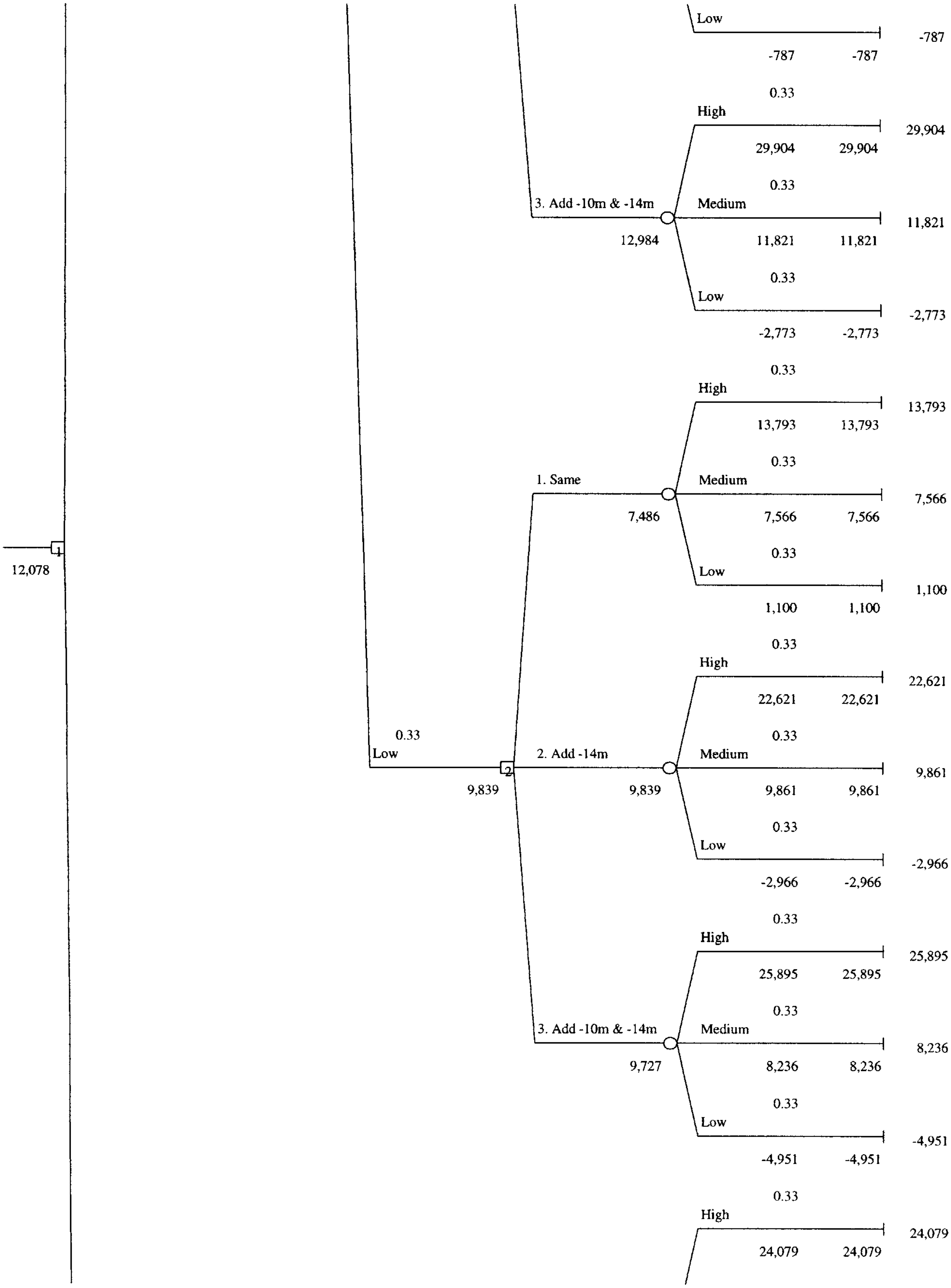



0.33
High
9,417
0.33
Medium
7,891
2. Add -14m
7,891
0.33
Medium
8,202
8,202
8,202
0.33
Low
-5,637
-5,637
-5,637
0.33
High
24,194
24,194
24,194
3. Add -10m & -14m
7,274
0.33
Medium
6,111
6,111
6,111
0.33
Low
-8,483
-8,483
-8,483
1. Same
4,504
0.33
High
10,811
10,811
10,811
0.33
Medium
4,583
4,583
4,583
0.33
Low
-1,882
-1,882
-1,882
0.33
Low
4,989
2. Add -14m
4,989
0.33
High
17,771
17,771
17,771
0.33
Medium
5,012
5,012
5,012
0.33
Low
-7,815
-7,815
-7,815
3. Add -10m & -14m
4,017
0.33
High
20,185
20,185
20,185
0.33
Medium
2,527
2,527
2,527
0.33
Low
-10,661
-10,661
-10,661

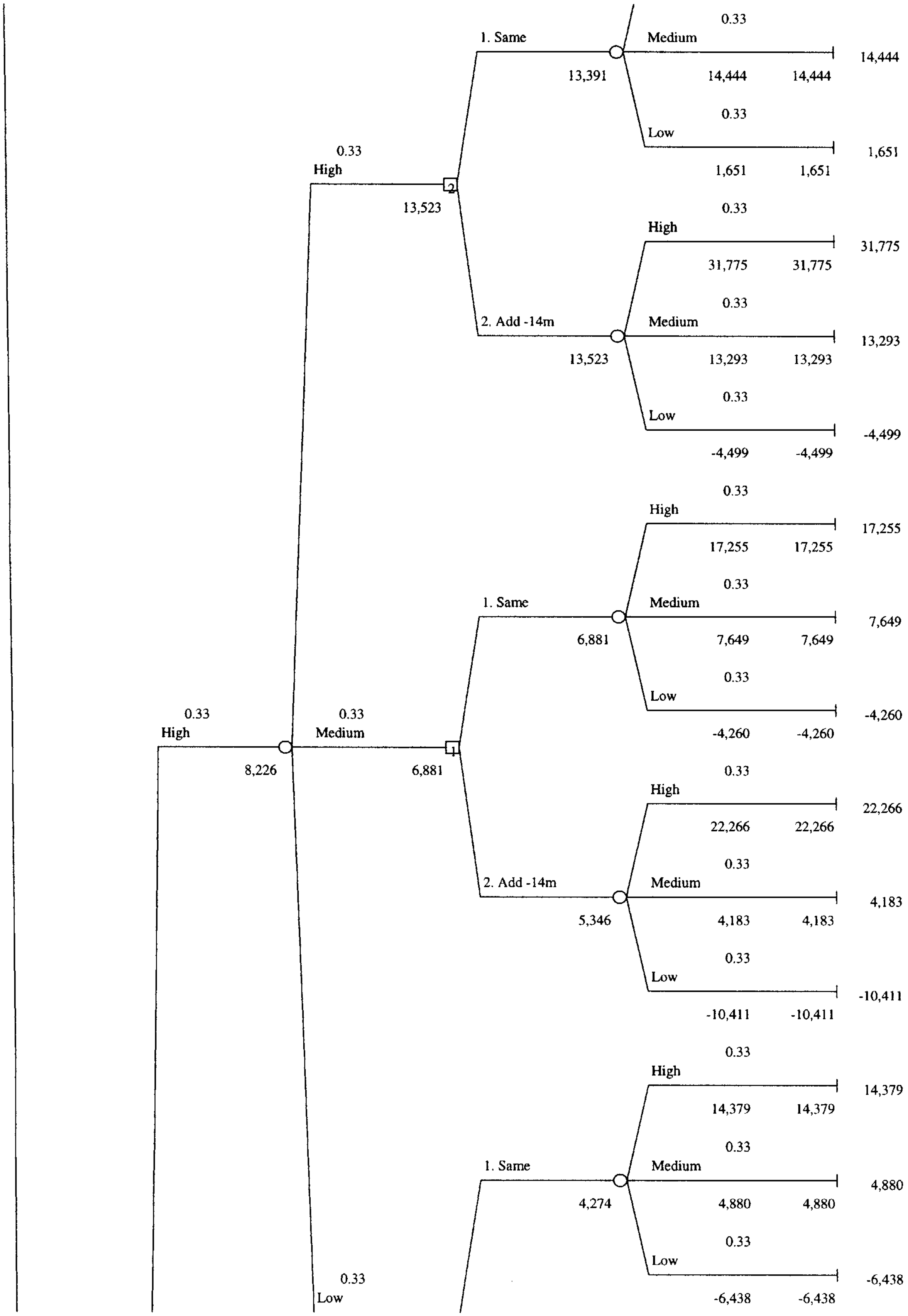

0.33
High
17,864
17,864
17,864
0.33
1. Same
Medium
13,081
12,495
13,081
13,081
0.33
Low
6,541
6,541
6,541
0.33
High
31,741
31,741
31,741
0.33
0.33
High
2. Add -14m
Medium
18,600
18,446
17,742
18,600
18,600
3
0.33
Low
2,886
2,886
2,886
0.33
High
36,778
36,778
36,778
0.33
3. Add -10m & -14m
Medium
18,058
18,446
18,058
18,058
0.33
Low
503
503
503
0.33
High
13,042
13,042
13,042
0.33
1. Same
Medium
8,163
7,614
8,163
8,163
0.33
Low
1,636
1,636
1,636
0.33
High
23,718
23,718
23,718
0.33
0.33
0.33
1. Build -14m
Medium
Medium
2
2. Add -14m
Medium
10,813

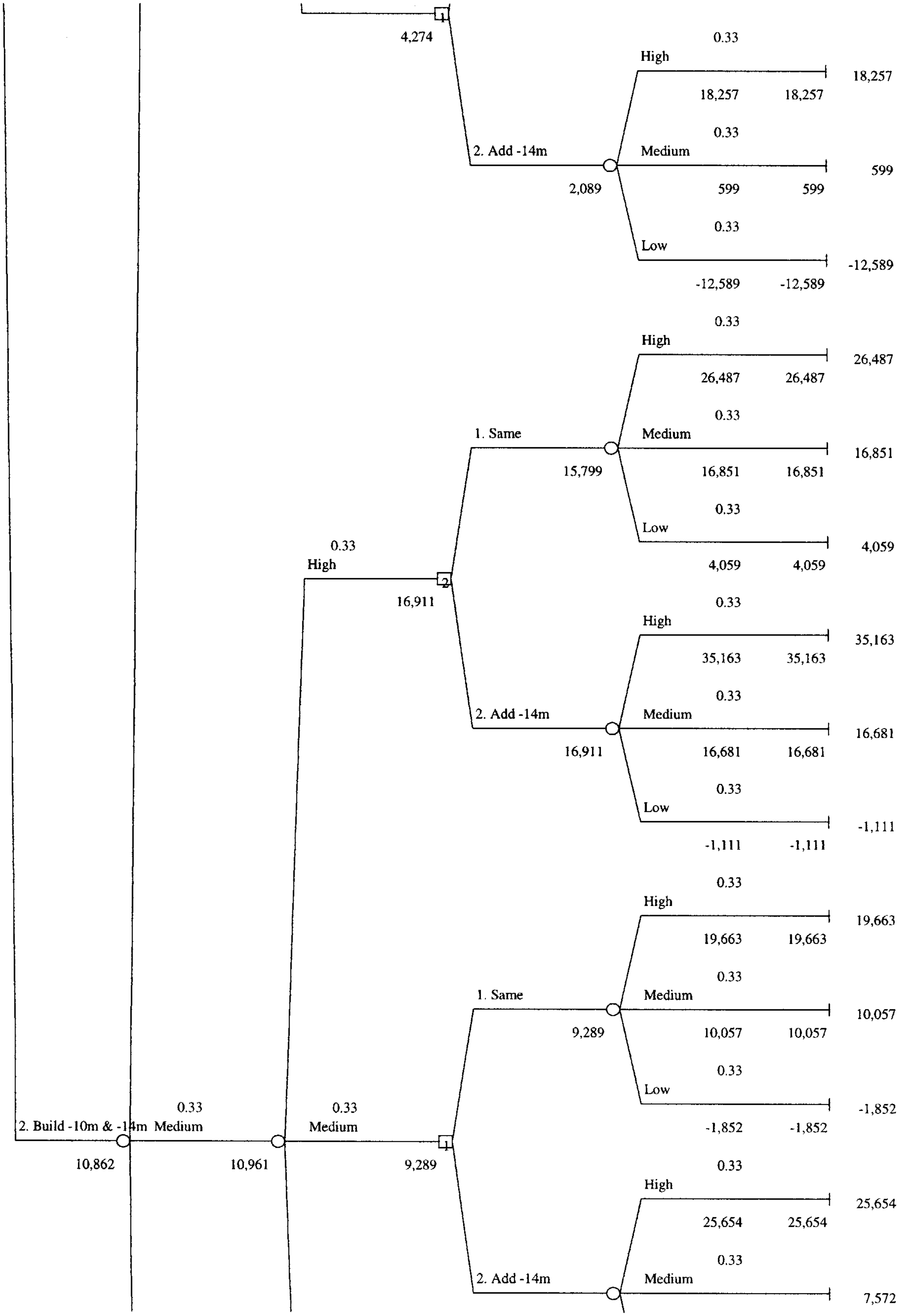

12,078
12,183
10,502
10,502
10,813
10,813
0.33
Low
-3,026
-3,026
-3,026
0.33
High
27,269
27,269
27,269
0.33
3. Add -10m & -14m
Medium
9,186
10,349
9,186
9,186
0.33
Low
-5,408
-5,408
-5,408
0.33
High
12,417
12,417
12,417
0.33
1. Same
Medium
6,189
6,110
6,189
6,189
0.33
Low
-277
-277
-277
0.33
High
20,383
20,383
20,383
0.33
0.33
Low
2. Add -14m
Medium
7,623
7,600
7,600
7,623
7,623
0.33
Low
-5,204
-5,204
-5,204
0.33
High
23,260
23,260
23,260
0.33
3. Add -10m & -14m
Medium
5,601
7,091
5,601
5,601
0.33
Low
-7,587
-7,587
-7,587
0.33
High

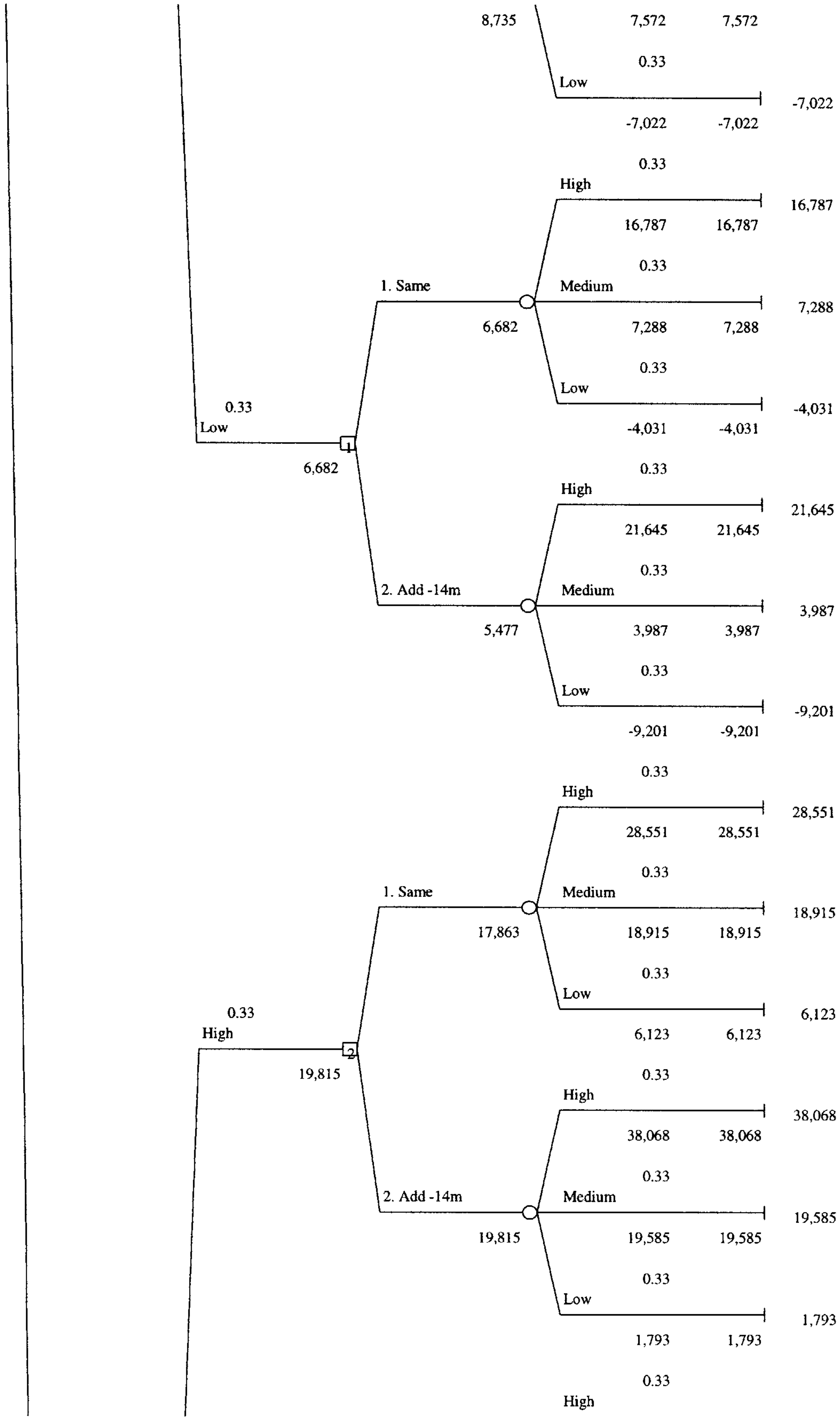

19,240
19,240
19,240
0.33
1. Same
Medium
14,458
13,872
14,458
14,458
0.33
Low
7,917
7,917
7,917
0.33
High
33,979
33,979
33,979
0.33
0.33
High
2. Add -14m
Medium
20,839
21,082
19,980
20,839
20,839
0.33
Low
5,124
5,124
5,124
0.33
High
39,413
39,413
39,413
0.33
3. Add -10m & -14m
Medium
20,694
21,082
20,694
20,694
0.33
Low
3,138
3,138
3,138
0.33
High
14,419
14,419
14,419
0.33
1. Same
Medium
9,540
8,990
9,540
9,540
0.33
Low
3,012
3,012
3,012
0.33
High
25,957
25,957
25,957
0.33
0.33
0.33
Low
Medium
2. Add -14m
Medium
13,051
14,635
12,984
12,740
13,051
13,051
0.33

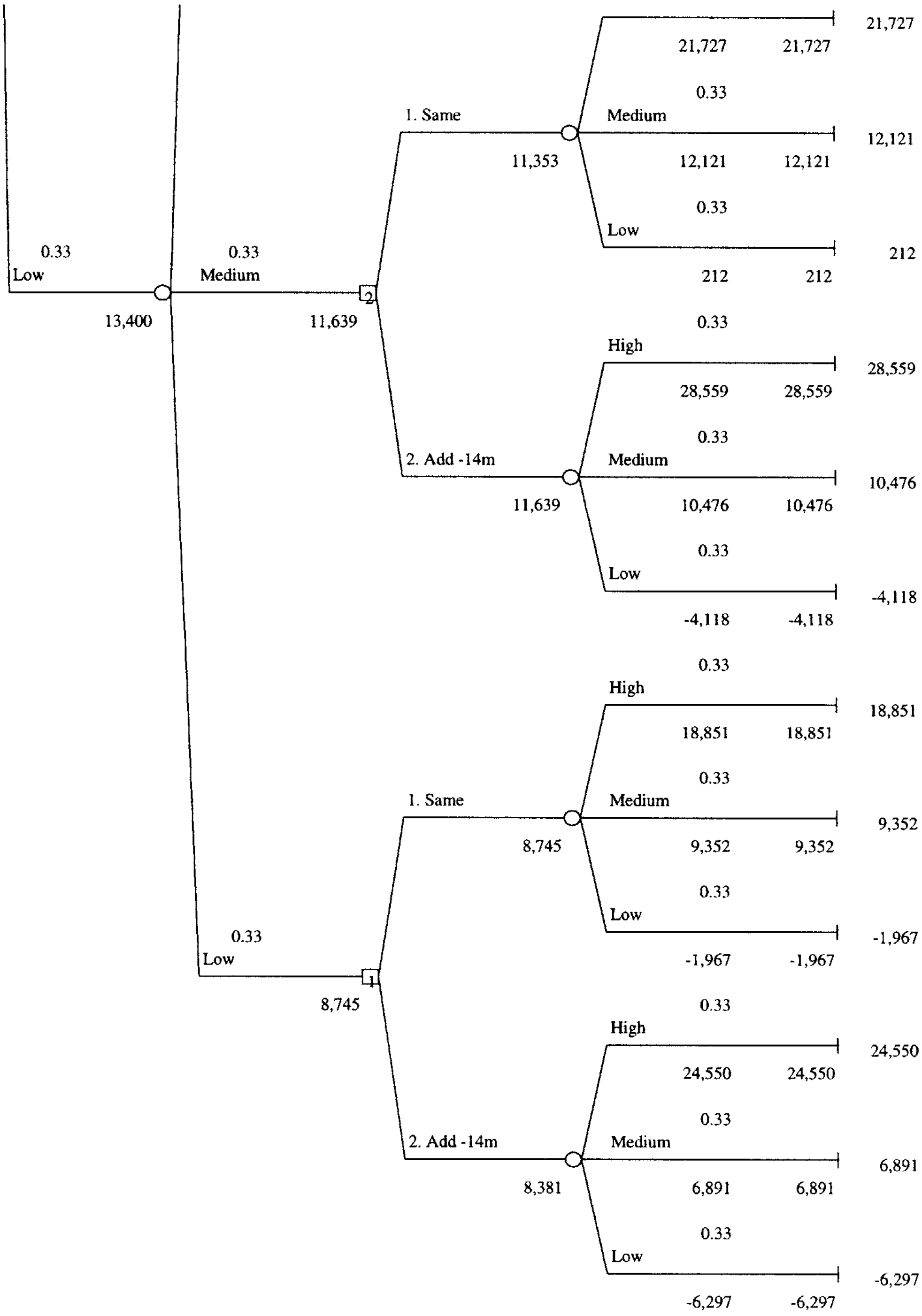


Low
-787
-787
-787
0.33
High
29,904
29,904
29,904
0.33
3. Add -10m & -14m
Medium
11,821
12,984
11,821
11,821
0.33
Low
-2,773
-2,773
-2,773
0.33
High
13,793
13,793
13,793
0.33
1. Same
Medium
7,566
7,486
7,566
7,566
0.33
Low
1,100
1,100
1,100
1
12,078
0.33
High
22,621
22,621
22,621
0.33
Low
2. Add -14m
Medium
9,861
2
9,839
9,839
9,861
9,861
0.33
Low
-2,966
-2,966
-2,966
0.33
High
25,895
25,895
25,895
0.33
3. Add -10m & -14m
Medium
8,236
9,727
8,236
8,236
0.33
Low
-4,951
-4,951
-4,951
0.33
High
24,079
24,079
24,079


0.33
Medium
1. Same
14,444
13,391
14,444
14,444
0.33
Low
1,651
0.33
High
1,651
1,651
13,523
0.33
High
31,775
31,775
31,775
0.33
Medium
2. Add -14m
13,293
13,523
13,293
13,293
0.33
Low
-4,499
-4,499
-4,499
0.33
High
17,255
17,255
17,255
0.33
1. Same
Medium
7,649
6,881
7,649
7,649
0.33
Low
-4,260
0.33
High
0.33
Medium
-4,260
-4,260
8,226
6,881
0.33
High
22,266
22,266
22,266
0.33
2. Add -14m
Medium
4,183
5,346
4,183
4,183
0.33
Low
-10,411
-10,411
-10,411
0.33
High
14,379
14,379
14,379
0.33
1. Same
Medium
4,880
4,274
4,880
4,880
0.33
Low
-6,438
0.33
Low
-6,438
-6,438


4,274
2. Add -14m
2,089
0.33
High
18,257
18,257
18,257
0.33
Medium
599
599
599
0.33
Low
-12,589
-12,589
-12,589
0.33
High
16,911
1. Same
15,799
0.33
High
26,487
26,487
26,487
0.33
Medium
16,851
16,851
16,851
0.33
Low
4,059
4,059
4,059
2. Add -14m
16,911
0.33
High
35,163
35,163
35,163
0.33
Medium
16,681
16,681
16,681
0.33
Low
-1,111
-1,111
-1,111
2. Build -10m & -14m
10,862
0.33
Medium
10,961
0.33
Medium
9,289
1. Same
9,289
0.33
High
19,663
19,663
19,663
0.33
Medium
10,057
10,057
10,057
0.33
Low
-1,852
-1,852
-1,852
2. Add -14m
0.33
High
25,654
25,654
25,654
0.33
Medium
7,572


8,735
7,572
7,572
0.33
Low
-7,022
-7,022
-7,022
0.33
High
16,787
16,787
16,787
1. Same
0.33
Medium
7,288
6,682
7,288
7,288
0.33
Low
-4,031
0.33
Low
-4,031
-4,031
6,682
0.33
High
21,645
21,645
21,645
0.33
2. Add -14m
Medium
3,987
5,477
3,987
3,987
0.33
Low
-9,201
-9,201
-9,201
0.33
High
28,551
28,551
28,551
0.33
1. Same
Medium
18,915
17,863
18,915
18,915
0.33
Low
6,123
0.33
High
6,123
6,123
19,815
0.33
High
38,068
38,068
38,068
0.33
2. Add -14m
Medium
19,585
19,815
19,585
19,585
0.33
Low
1,793
1,793
1,793
0.33
High


21,727
21,727
21,727
0.33
1. Same
Medium
12,121
11,353
12,121
12,121
0.33
Low
0.33
0.33
212
Low
Medium
13,400
11,639
212
212
0.33
High
28,559
28,559
28,559
0.33
2. Add -14m
Medium
10,476
11,639
10,476
10,476
0.33
Low
-4,118
-4,118
-4,118
0.33
High
18,851
18,851
18,851
0.33
1. Same
Medium
9,352
8,745
9,352
9,352
0.33
Low
-1,967
0.33
Low
-1,967
-1,967
8,745
0.33
High
24,550
24,550
24,550
0.33
2. Add -14m
Medium
6,891
8,381
6,891
6,891
0.33
Low
-6,297
-6,297
-6,297

Appendix 4: Monte-Carlo simulation for Case Study

1. Base Expected NPV

Using the statistical information (distribution, mean, and standard deviation) introduced in Appendix 2, Monte-Carlo simulation first generates ten realizations of demand growth paths. The average NPV of the ten realizations for the Phase 1 investment gives a Base Expected NPV for the Phase 1 facilities. (Here, the Phase 2 decision is not taken into account.)

2. Option value

For each one of above ten realizations, ten further realizations of demand growth paths are generated for the period after Year 11 (thus resulting in 100 realizations of project demand growth paths after the Phase 2 decision). The option value is realized when the expected value of expansion, given information on Phase 1, is greater than the expected value of non-expansion. The option value arises by resolutions of demand uncertainty and cost uncertainty. (Because market demand uncertainty is never resolved, it has nothing to do with option value here. All option value coming from the resolution of demand uncertainty is attributed to the resolution of the project share uncertainty.)

Table A4-1: Generated Project demand by Monte-Carlo Simulation (Unit: 1,000 ton)

Demand for Base NPV

Year	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Demand 1	131	143	146	154	157	185	218	252	289	332	392	443	510	563	655	731	798	890	932	1033	1180	1343	1478	1638	1830	2044	2165	2349	2566	2897
Demand 2	30	33	36	37	40	59	85	126	175	223	271	322	370	426	509	569	651	744	843	945	1038	1138	1244	1444	1598	1870	2120	2333	2558	2842
Demand 3	113	120	129	132	133	163	202	247	288	341	383	454	518	607	684	735	834	935	1097	1154	1229	1384	1554	1742	1925	2173	2452	2674	2903	3134
Demand 4	62	64	63	68	73	97	129	173	201	238	283	329	365	426	511	607	700	803	905	1001	1089	1209	1381	1512	1668	1829	2054	2244	2457	2703
Demand 5	120	126	134	145	159	189	223	263	299	338	398	455	511	571	606	645	685	764	852	911	981	1079	1197	1315	1465	1619	1788	1967	2109	2413
Demand 6	72	75	80	85	91	113	140	175	206	251	310	380	429	480	539	619	694	789	886	960	1046	1190	1299	1437	1527	1644	1762	1977	2193	2486
Demand 7	13	14	14	14	14	31	49	71	93	116	153	176	214	248	308	349	406	464	542	628	688	775	843	905	959	1061	1181	1341	1507	1608
Demand 8	40	43	47	49	53	91	116	145	174	224	259	298	337	381	442	513	606	731	835	951	1058	1209	1340	1470	1705	1925	2161	2348	2486	2781
Demand 9	51	53	59	63	65	88	111	127	165	204	242	296	334	380	443	546	621	717	828	927	1033	1189	1338	1495	1665	1839	2061	2325	2622	2972
Demand 10	46	49	53	56	60	86	114	145	173	223	258	301	338	416	487	553	609	675	788	880	985	1086	1166	1375	1510	1673	1774	2008	2161	2415

Example of demand generation after the five year operation (the case after Demand 1)

Year	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Demand1-1	185	222	262	294	345	396	462	502	560	627	685	768	855	941	1042	1153	1251	1396	1518	1671	1871	2072	2281	2493	2704
Demand1-2	181	217	254	308	354	390	427	476	544	625	680	769	839	942	1034	1133	1252	1416	1602	1729	1949	2141	2293	2593	2832
Demand1-3	193	224	261	313	347	401	452	525	571	624	696	762	820	898	1021	1160	1343	1425	1563	1693	1794	1920	2008	2190	2391
Demand1-4	189	233	278	306	351	385	448	517	577	664	744	823	894	1023	1070	1202	1319	1447	1572	1766	1846	2119	2318	2529	2828
Demand1-5	182	224	254	297	328	376	431	509	558	621	719	794	885	986	1070	1169	1239	1373	1475	1633	1760	1938	2123	2362	2482
Demand1-6	196	221	258	296	350	416	470	562	618	698	796	886	1012	1056	1160	1251	1399	1594	1786	2086	2216	2411	2618	2868	3138
Demand1-7	188	219	254	294	322	355	411	472	544	652	751	819	937	1021	1157	1258	1353	1467	1554	1685	1825	2061	2176	2327	2557
Demand1-8	191	231	268	317	365	423	477	527	598	630	725	797	876	944	1091	1201	1329	1457	1599	1734	1860	2033	2263	2496	2708
Demand1-9	182	203	248	287	332	399	457	494	557	586	613	695	763	845	947	1059	1163	1217	1377	1513	1680	1816	1948	2225	2517
Demand1-10	181	217	257	284	325	372	418	468	517	570	615	660	747	803	854	932	1079	1220	1366	1524	1656	1730	1893	2150	2365

Table A4-2: Monte-Carlo Simulation for Choice 1 (NPV Unit: 1,000 Yen)

(-14m berth for Phase1 with expansion options: 1.-14m berth, 2. -14m & -10m berths at year 10)

Outcome Summary

	Base Expected	Option Value	Total
NPV	**9,619,980**	**3,578,816**	**13,198,796**
High cost	8,050,911	-	-
Medium cost	9,702,563	-	-
Low cost	11,106,467	-	-

▨ Decision taken for Phase 2

After Demand 1

	Expansion1	Expansion2	No Expansion	Option Value	
Expected Value	18,443,442	17,742,222	13,538,543	4,904,899	
High cost	15,891,999	14,738,084	11,969,473	3,922,526	*
Medium cost	18,577,728	17,900,334	13,621,125	4,956,603	*
Low cost	20,860,597	20,588,246	15,025,030	5,835,568	*

After Demand 2

	Expansion1	Expansion2	No Expansion	Option Value	
Expected Value	10,672,496	9,490,310	7,764,703	2,907,793	
High cost	8,121,053	6,486,173	6,195,633	1,925,420	*
Medium cost	10,806,782	9,648,423	7,847,285	2,959,497	*
Low cost	13,089,651	12,336,335	9,251,190	3,838,461	*

After Demand 3

	Expansion1	Expansion2	No Expansion	Option Value	
Expected Value	20,027,475	20,607,662	13,254,872	7,352,790	
High cost	17,476,033	17,603,525	11,685,802	5,917,723	*
Medium cost	20,161,761	20,765,775	13,337,454	7,428,320	*
Low cost	22,444,630	23,453,687	14,741,359	8,712,328	*

After Demand 4

	Expansion1	Expansion2	No Expansion	Option Value	
Expected Value	9,964,929	8,272,956	7,959,307	2,005,621	
High cost	7,413,486	5,268,819	6,390,238	1,023,249	*
Medium cost	10,099,215	8,431,069	8,041,890	2,057,325	*
Low cost	12,382,084	11,118,981	9,445,794	2,936,290	*

After Demand 5

	Expansion1	Expansion2	No Expansion	Option Value	
Expected Value	20,617,382	20,820,337	14,115,080	6,788,504	
High cost	18,065,940	17,816,200	12,546,010	5,519,930	*
Medium cost	20,751,669	20,978,449	14,197,662	6,780,787	*
Low cost	23,034,538	23,666,361	15,601,567	8,064,795	*

After Demand 6

	Expansion1	Expansion2	No Expansion	Option Value	
Expected Value	12,994,492	11,626,736	9,730,274	3,264,219	*
High cost	10,443,050	8,622,599	8,161,204	2,281,846	*
Medium cost	13,128,779	11,784,849	9,812,856	3,315,923	*
Low cost	15,411,648	14,472,761	11,216,761	4,194,888	

After Demand 7

	Expansion1	Expansion2	No Expansion	Option Value	
Expected Value	2,745,914	416,837	3,629,259	15,774	
High cost	194,472	-2,587,300	2,060,190	0	*
Medium cost	2,880,200	574,949	3,711,842	0	*
Low cost	5,163,070	3,262,861	5,115,746	47,323	*

After Demand 8

	Expansion1	Expansion2	No Expansion	Option Value	
Expected Value	12,393,383	11,263,063	8,804,160	3,589,223	
High cost	9,841,941	8,258,926	7,235,090	2,606,851	*
Medium cost	12,527,669	11,421,176	8,886,742	3,640,927	*
Low cost	14,810,539	14,109,088	10,290,647	4,519,892	*

After Demand 9

	Expansion1	Expansion2	No Expansion	Option Value	
Expected Value	9,280,800	7,427,103	7,482,572	1,798,227	
High cost	6,729,358	4,422,966	5,913,503	815,855	*
Medium cost	9,415,086	7,585,216	7,565,155	1,849,931	*
Low cost	11,697,955	10,273,128	8,969,059	2,728,896	*

After Demand 10

	Expansion1	Expansion2	No Expansion	Option Value	
Expected Value	11,976,239	10,720,198	8,815,129	3,161,109	
High cost	9,424,797	7,716,060	7,246,060	2,178,737	*
Medium cost	12,110,525	10,878,310	8,897,712	3,212,813	*
Low cost	14,393,395	13,566,222	10,301,616	4,091,778	*

* Option Value = Max(Expansion1, Expansion2, No Expansion) - No Expansion

Table A4-3: Monte-Carlo Simulation for Choice 2 (NPV Unit: 1,000 Yen)
(-14m & -10m berths for Phase 1 with an expansion option (-14m berth) at Year 10)

Outcome Summary

	Base Expected	**Option Value**	**Total**
NPV	**12,017,033**	**209,911**	**12,226,944**
High cost	9,688,571	-	-
Medium cost	12,139,584	-	-
Low cost	14,222,945	-	-

▨ Decision to be taken for Phase 2

After Demand 1

	Expansion	**No Expansion**	**Option Value**	
Expected Value	16,111,882	16,978,952	21,199	
High cost	12,801,047	14,650,490	0	*
Medium cost	16,286,136	17,101,503	0	*
Low cost	19,248,462	19,184,864	63,598	*

After Demand 2

	Expansion	**No Expansion**	**Option Value**	
Expected Value	7,859,970	9,759,363	0	
High cost	4,549,136	7,430,901	0	*
Medium cost	8,034,225	9,881,914	0	*
Low cost	10,996,551	11,965,275	0	*

After Demand 3

	Expansion	**No Expansion**	**Option Value**	
Expected Value	18,977,322	17,687,467	1,289,855	
High cost	15,666,487	15,359,005	307,482	*
Medium cost	19,151,577	17,810,018	1,341,559	*
Low cost	22,113,902	19,893,379	2,220,524	*

After Demand 4

	Expansion	**No Expansion**	**Option Value**	
Expected Value	6,642,616	9,430,803	0	
High cost	3,331,782	7,102,341	0	*
Medium cost	6,816,871	9,553,354	0	*
Low cost	9,779,196	11,636,714	0	*

After Demand 5

	Expansion	**No Expansion**	**Option Value**	
Expected Value	19,189,997	18,499,102	788,054	
High cost	15,879,162	16,170,640	0	*
Medium cost	19,364,251	18,621,653	742,598	*
Low cost	22,326,577	20,705,014	1,621,563	*

After Demand 6

	Expansion	No Expansion	Option Value	
Expected Value	9,996,397	12,071,596	0	*
High cost	6,685,562	9,743,134	0	*
Medium cost	10,170,651	12,194,147	0	*
Low cost	13,132,977	14,277,508	0	

After Demand 7

	Expansion	No Expansion	Option Value	
Expected Value	-1,213,503	3,153,403	0	
High cost	-4,524,338	824,941	0	*
Medium cost	-1,039,249	3,275,954	0	*
Low cost	1,923,077	5,359,314	0	*

After Demand 8

	Expansion	No Expansion	Option Value	
Expected Value	9,632,723	11,262,155	0	
High cost	6,321,889	8,933,693	0	*
Medium cost	9,806,978	11,384,705	0	*
Low cost	12,769,303	13,468,066	0	*

After Demand 9

	Expansion	No Expansion	Option Value	
Expected Value	5,796,764	8,797,724	0	
High cost	2,485,929	6,469,262	0	*
Medium cost	5,971,018	8,920,275	0	*
Low cost	8,933,344	11,003,636	0	*

After Demand 10

	Expansion	No Expansion	Option Value	
Expected Value	9,089,858	11,082,280	0	
High cost	5,779,023	8,753,818	0	*
Medium cost	9,264,112	11,204,830	0	*
Low cost	12,226,438	13,288,191	0	*

* Option Value = Max(Expansion, No Expansion) - No Expansion

Appendix 5: Black-Scholes equation for Case Study

The Black Scholes valuation for the case study is basically the same as that in Chapter 3. Applying the Black-Scholes equation, $V = N(d1)*A - N(d2)*X*\exp(-rf*T)$, to the case study:

V = Current value of call option

A = Expected value of additional net benefit flow by expansion (Current value of underlying asset)

X = Cost of expansion

$rf = 4\%$ (assumption)

T = 10 years (five years for construction of Phase 1 facilities and five years of operation)

$N(d1)$ and $N(d2)$ are the values of the normal distribution at d1 and d2

$d1 = [\ln(A/X) + (r + 0.5*\sigma^2)*T\ ]/(\ \sigma*T^{0.5})$

$d2 = d1 - \sigma*T^{0.5}$

σ = Volatility of the underlying asset

Here, because there are no *a priori* data on the underlying asset and its volatility for this particular case, the realizations of the Monte-Carlo simulation calculated before are used in valuing them. The expected value calculated from the initially generated ten demand growth paths can be seen as the current value of the underlying asset.

The expected value calculated from ten further realizations of demand paths for the period after Year 11 for each realization of the initially generated ten demand growth paths can be seen as each value that the underlying asset can have in ten years.

Here, in order to deal with the uncertainty in exercise price (construction cost), high construction cost is used for X, the exercise price, and the difference between high construction cost and medium/low construction cost is added to the net benefit. Thus, 30 (10 demand growth paths*3 costs) underlying asset values in ten years are obtained. Then the ratio of each value to the current value is calculated. Standard deviation of the natural log of the ratio is assumed as ten year volatility. Annual volatility is then obtained by dividing it by ten.

It should be noted that the option value of Choice 1 is not the option value of adding a –14m berth and a –10m berth to existing –14m berth, but the sum of the option value of adding a –14m berth to the existing –14m berth (4,116 million Yen) and the option value of adding a –10m berth to two –14m berths (262 million Yen), as Chapter 3 explains.

Table A5-1: Volatility of Asset Value with Choice 1
(Additional net benefit by adding a -14m berth to one -14m berth)
(unit: 1,000 Yen)

Current Value	10,810,623

* Expected value is calculated using initialy generated Demand 1 ~ Demand 10.

Demand case	Cost case	Value	Ratio (to Current)	Ln(Ratio)
1-1 ~ 1-10	High	10,205,393	0.94402	-0.05761
	Medium	11,857,045	1.09680	0.09239
	Low	13,260,949	1.22666	0.20429
2-1 ~ 2-10	High	8,521,723	0.78827	-0.23791
	Medium	10,173,375	0.94105	-0.06076
	Low	11,577,280	1.07092	0.06852
3-1 ~ 3-10	High	12,643,654	1.16956	0.15663
	Medium	14,295,307	1.32234	0.27940
	Low	15,699,211	1.45220	0.37308
4-1 ~ 4-10	High	7,438,204	0.68805	-0.37390
	Medium	9,089,856	0.84083	-0.17337
	Low	10,493,761	0.97069	-0.02975
5-1 ~ 5-10	High	12,015,741	1.11148	0.10569
	Medium	13,667,393	1.26426	0.23448
	Low	15,071,298	1.39412	0.33226
6-1 ~ 6-10	High	8,556,282	0.79147	-0.23386
	Medium	10,207,934	0.94425	-0.05736
	Low	11,611,838	1.07411	0.07150
7-1 ~ 7-10	High	4,338,740	0.40134	-0.91295
	Medium	5,990,393	0.55412	-0.59037
	Low	7,394,297	0.68398	-0.37982
8-1 ~ 8-10	High	8,830,890	0.81687	-0.20227
	Medium	10,482,542	0.96965	-0.03082
	Low	11,886,447	1.09952	0.09487
9-1 ~ 9-10	High	7,032,280	0.65050	-0.43002
	Medium	8,683,932	0.80328	-0.21905
	Low	10,087,837	0.93314	-0.06920
10-1 ~ 10-10	High	8,449,050	0.78155	-0.24648
	Medium	10,100,702	0.93433	-0.06792
	Low	11,504,606	1.06419	0.06222
			Volatility (10 yrs.)	28.9%
			Annual Volatility	2.9%

Table A5-2: Option value with Choice 1						
(Expansion option of adding a -14m berth to one -14m berth)						
Black-Scholes Model	Calculates value of European call. (Currency Unit: 1,000Yen)					
A	10,810,623					
X	9,909,913					
1 + rf	1.04					
t	10	yrs				
Sigma	2.9%					
d1	**N(d1)**	**d2**	**N(d2)**			
5.285	1.000	5.194	1.000			
Call Value	4,115,841					

Table A5-3: Volatility of Asset Value with Choice 1
(Additional net benefit by adding a -10m berth to two -14m berths)
(unit: 1,000 Yen)

Current Value	2,270,849

* Expected value is calculated using initialy generated Demand 1 ~ Demand 10.

Demand case	Cost case	Value	Ratio (to Current)	Ln(Ratio)
1-1 ~ 1-10	High	1,705,210	0.75091	-0.28647
	Medium	2,354,457	1.03682	0.03616
	Low	2,906,316	1.27984	0.24673
2-1 ~ 2-10	High	1,224,245	0.53911	-0.61783
	Medium	1,873,492	0.82502	-0.19235
	Low	2,425,351	1.06804	0.06582
3-1 ~ 3-10	High	2,986,618	1.31520	0.27399
	Medium	3,635,864	1.60110	0.47069
	Low	4,187,723	1.84412	0.61200
4-1 ~ 4-10	High	714,458	0.31462	-1.15638
	Medium	1,363,704	0.60053	-0.50995
	Low	1,915,564	0.84355	-0.17014
5-1 ~ 5-10	High	2,609,385	1.14908	0.13896
	Medium	3,258,631	1.43498	0.36115
	Low	3,810,490	1.67800	0.51760
6-1 ~ 6-10	High	1,038,675	0.45739	-0.78221
	Medium	1,687,921	0.74330	-0.29666
	Low	2,239,780	0.98632	-0.01378
7-1 ~ 7-10	High	77,353	0.03406	-3.37953
	Medium	726,600	0.31997	-1.13953
	Low	1,278,459	0.56299	-0.57450
8-1 ~ 8-10	High	1,276,111	0.56195	-0.57634
	Medium	1,925,357	0.84786	-0.16504
	Low	2,477,216	1.09088	0.08698
9-1 ~ 9-10	High	552,734	0.24340	-1.41303
	Medium	1,201,980	0.52931	-0.63618
	Low	1,753,840	0.77233	-0.25835
10-1 ~ 10-10	High	1,150,389	0.50659	-0.68005
	Medium	1,799,635	0.79249	-0.23257
	Low	2,351,495	1.03551	0.03490
			Volatility (10 yrs.)	76.3%
			Annual Volatility	7.9%

Table A5-4: Option value with Choice 1							
(Expansion option of adding a -10m berth to two -14m berths)							
Black-Scholes Model	Calculates value of European call. (Currency Unit: 1,000Yen)						
A	2,270,849						
X	3,246,231						
1 + rf	1.04						
t	10	yrs					
Sigma	7.9%						
d1	**N(d1)**	**d2**	**N(d2)**				
0.265	0.604	0.016	0.506				
Call Value	262,140						

Table A5-5: Volatility of Asset Value with Choice 2
(Additional net benefit by adding a -14m berth to -10m & -14m berths)
(unit: 1,000 Yen)

Current Value	5,567,548

* Expected value is calculated using initialy generated Demand 1 ~ Demand 10.

Demand case	Cost case	Value (1,000 Yen)	Ratio (to Current)	Ln(Ratio)
1-1 ~ 1-10	High	4,355,015	0.78221	-0.24563
	Medium	6,006,668	1.07887	0.07592
	Low	7,410,572	1.33103	0.28595
2-1 ~ 2-10	High	3,322,693	0.59680	-0.51618
	Medium	4,974,345	0.89345	-0.11266
	Low	6,378,250	1.14561	0.13594
3-1 ~ 3-10	High	6,511,941	1.16962	0.15668
	Medium	8,163,593	1.46628	0.38273
	Low	9,567,497	1.71844	0.54142
4-1 ~ 4-10	High	2,433,899	0.43716	-0.82746
	Medium	4,085,551	0.73382	-0.30950
	Low	5,489,456	0.98597	-0.01413
5-1 ~ 5-10	High	5,912,980	1.06204	0.06020
	Medium	7,564,632	1.35870	0.30653
	Low	8,968,537	1.61086	0.47677
6-1 ~ 6-10	High	3,146,886	0.56522	-0.57054
	Medium	4,798,538	0.86188	-0.14864
	Low	6,202,443	1.11403	0.10799
7-1 ~ 7-10	High	855,180	0.15360	-1.87340
	Medium	2,506,832	0.45026	-0.79794
	Low	3,910,736	0.70242	-0.35323
8-1 ~ 8-10	High	3,592,654	0.64528	-0.43806
	Medium	5,244,307	0.94194	-0.05981
	Low	6,648,211	1.19410	0.17739
9-1 ~ 9-10	High	2,221,125	0.39894	-0.91894
	Medium	3,872,778	0.69560	-0.36298
	Low	5,276,682	0.94776	-0.05366
10-1 ~ 10-10	High	4,355,015	0.78221	-0.24563
	Medium	6,006,668	1.07887	0.07592
	Low	7,410,572	1.33103	0.28595
			Volatility (10yrs)	50.8%
			Annual Volatility	5.1%

Table A5-6: Option value with Choice 2
(Expansion option of adding a -14m berth to -14m & -10m berths)

Black-Scholes Model	Calculates value of European call. (Currency Unit: 1,000Yen)					
A	5,567,548					
X	9,909,913					
1 + rf	1.04					
t	10	yrs				
Sigma	5.1%					
d1	**N(d1)**	**d2**	**N(d2)**			
-1.067	0.143	-1.228	0.110			
Call Value	61,063					