A Case Study of Membrane Ceilings Business Using A Real Options Approach

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Abstract

This study picks up an existing company and conduct a case study with respect to a new business for the company. In this case study, we observe that the company is starting a membrane ceilings business in addition to the existing business; sales of iron. In the paper, we apply the real option approach to the actual business and evaluate it. We provide valuable implication with regard to the managerial decision under uncertainty. In addition to the standard option pricing theory, we also take model risk into account. For this reason, we take the parameters of the model as random variables. It enables us to examine the effect of the ambiguity on the optimal decision for the company. In order to analyze the actual business, we develop a systematic approach in analyzing managerial flexibility under uncertainty. The approach includes specifying important risk factors, parameter estimation, handling the ambiguity, and deriving the optimal strategy. Our analysis reveals that the company has two real options under uncertainty with respect to a market price and demand. We show that the options have a significant impact on the project value of the membrane ceilings. We also show that the presence of the model risk could change the optimal managerial decision when to expand the new business.

Keywords: case study, real options, ambiguity

1. Introduction

Real options have been actively investigated since they are introduced in 1970s. Application of the real option to business practices has been seriously discussed in 1990s. Although the importance of case studies on real options are widely known among researchers, the number of them are currently quite limited due to the following reasons. Firstly, the framework of applying real options to a business practice is unclear. Without the framework, it is difficult for practitioners to put the real option approach into practice. The second reason is complexity of quantification. In particular, several researches point out that the company

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needs mathematical techniques to understand the option pricing theory. Finally, it is often the case in many other economic theories, there is a big gap between theory and practice. Though the theory of real options have been developed, it is hard to utilize it for business.

In theory, real options can be applied to various kinds of problems. Amongst them, a new business is one of the major topics particularly because it has high uncertainty and flexibility in future. Starting a new business is riskier because it involve various kinds of uncertainties. Furthermore, it is difficult to recognize them precisely, that is, the company does not have any business experience, and no data is available in the current market. For these reasons, there are a large number of theoretical studies that analyze new businesses with real options, such as an entry to a new market and evaluating R&D (See, Dixit (1989) and Shockley, Curtis, Jafari, and Tibbs (2002), for example).

In this paper, we picks up an existing company and conduct a case study with respect to a new business for the company. The company is starting a membrane ceilings business in addition to sales of iron as the existing business. We discuss a practically reasonable investment decision under uncertainty of both a commodity price and demand fluctuations. Because membrane ceilings are relatively new products, their market is not well established. Furthermore, the company needs to take other possibilities that could affect its business profitability, such as a surge in demand and entry of new competitors. It means that this business is highly uncertain. However, the company could have many types of flexibility at the same time. Accordingly, it is reasonable to consider that the real option approach is promising to analyze the business profitability and the optimal decision under these uncertainties.

Let use summarize difficulties we face in analyzing the real case study and solutions we use. First, the chief manager of the company did not know anything about the real options although he had basic knowledge about NPV analysis. Even if he has no idea about real options, he might have the way of thinking of real options. Therefore, we interview with him without using technical words to grasp the present situation and identify elements needed for our analysis.

Second, for the quantitative real option analysis, it is necessary to specify the underlying model, specify the flexibility that the company might have, and estimate parameter values under limited information. In applying the real option approach to the actual business, we need to determine whether each assumption used in theoretical studies is validated. For example, we decide to employ a geometric Brownian motion as the underlying risk processes since it is good for the approximation, but we decide not use the risk neutral valuation since no-arbitrage condition is not appropriate for the analysis.

Third, even though we decide the model we use, we do not know how to determine parameters of a model when the company has no past data. One of the methods of solving the difficulty is to extract the information from the manager's foresight. However, we recognize that the manager's prediction could contain bias and misspecification. To deal with them, in this paper, we begin with our analysis that is based on the manager's belief, and later examine it in the presence of ambiguity in response to the manager's possible misspecification.

Finally, we must identify real options, i.e, managerial flexibility of the company. From a theoretical viewpoint, the company has many types of real options. On the other hand, in practice, they are not always existent nor important. Therefore, we need to identify existent real options that affect the value of the new business. In this paper, we develop a systematic approach in analyzing managerial flexibility under uncertainty. For this purpose we refer to ideas in Trigeorgis and Reuer (2017), Tchankova (2002), and Copeland and Antikarov (2001). It includes specifying important risk factors, parameter estimation, handling the ambiguity and deriving the optimal strategy.

The paper is organized as follows. We explain a case of this study in Section 2. The features of the company and the new project are introduced. We also identify risks and options of the project in the section. Section 3 presents the estimation method of the project. We refer to an NPV analysis, a Monte Carlo DCF technique and a real options approach. In Section 4, we show results and discussion Section 5 concludes this paper.

2. Descriptions of the case study

2.1. Case-study background

The company of this study has engaged in construction industry for more than half a century in Japan. It is exposed to material cost changes and demand changes. The entire construction industry is currently booming thanks to great demands of the Tokyo 2020 Olympic Games. The manager, nevertheless, realizes potential risk about falling demands after the games. He also pays attention to the market risk in iron prices. As a result, he decides to explore a new business that deals with membrane ceilings during the current boom so that the company prepares for a potential downside in the future. We pick up this new business as a case and evaluate its profitability and risk.

2.2. Membrane ceilings

It is known that Japan is heavily exposed to risk for earthquakes. Hence, it is urgent to prevent from secondary damage. The collapse of a building during the earthquake is one of the most serious dangers. For example, the collapse of ceilings of a shelter poses physical threats to many residents when an earthquake happens. To prepare for the potential danger, Ministry of Land, Infrastructure, Transport and Tourism operated on government ordinances in 2014. One of the promising ways to resolve the danger is to adopt membrane ceilings. Because of their light weights, we can prevent the ceilings from falling, and the damage could be less serious even if they are collapsed. The membrane ceilings have other advantages, that is, they are shock-resistant and tough. In summary, the membrane ceilings have many attractive features for Japanese citizens.

It is also attractive for the company to install the membrane ceiling as a new business. The company can handle interior design in addition to the existing business. The current business of the company is mainly to sell steel to clients. Hence, selling the membrane ceilings can expand the capacity of business beyond material sales. Another merit is that the membrane ceilings business is promising. Membrane ceilings are not only light but also superior to a design property. It seems reasonable to assume that the business will be combined with a lighting business because they are permeable.

2.3. Four steps for analyzing the new business

Fig. 1 illustrates four steps of analysis developed in this paper. Firs of all, it is important to recognize that before applying real option approach and valuing the project in step 4, three pre-evaluation steps are required; that is, identification of important risk factors (step 1: Identification 1), identification of important managerial flexibility(step 2: Identification 2), and estimation of the model parameter values (step 3: Estimation). All the data and information of the steps are obtained from the company and interviews with the chief manager of the company.

Table 1 summarizes representative risks and flexibility in the membrane business. In step 1, we refer to the way proposed in Tchankova (2002) to identify risks exposed in the new business. They are summarized in the column labeled "Representative risks" .

In step 2, we identify real options in response to the risks identified in step 1. Trigeorgis and Reuer (2017) discussed a genral idea how to identify the options, hence we specify them based on it. The column labeled "Representative flexibility" in Table 1 can be classified as follows. First one is to establish a processing plant for increasing the products. The plant enables us to reduce costs of transportation and manufacturing times. By building it, the company can also change basic squares of membrane ceilings to desirable size ceilings and different shapes. Price of the circular membrane ceilings is more expensive than that of basic ones. In addition, the company can differentiate themselves from other companies by selling the circular membrane ceilings. In the future, it is expected to make other shapes such as toroidal in the plant.

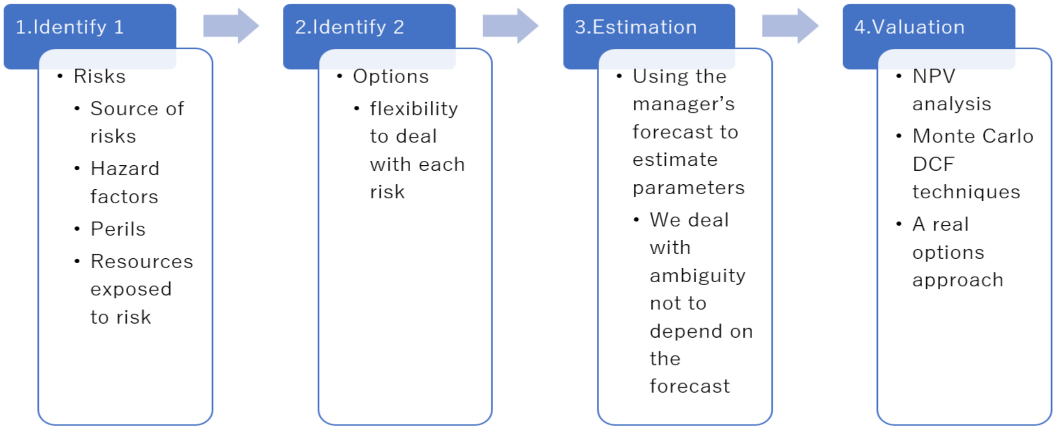

Fig. 1. Four steps of analysis

Second flexibility is to respond to a wide range of necessities such as exhibition rooms. While the membrane ceilings are mainly used for public facilities currently, it is considered that their features are utilized in various places. Moreover, the business is related to a lighting business. Therefore, if the lighting business is started, it is possible for the company to create synergy between the pre-existing business, the membrane ceilings business and the new business.

As the third flexibility, the company is able to add a different product to meet a Japanese standard. The company provided only fireproof ceilings when it started the membrane business. As times went on, the company knew that nonflammable ceilings were required in Japan. Thus, selling membrane ceilings made of nonflammable materials is paramount. The company will have to find and develop new characteristics in the future. In addition, it is needed to identify the strength of membrane ceilings possibly. To quantify the strength, the company requires to ask for others or to build a laboratory.

As summarized in Table 1, the company have difference sources of risk and many real options. For a practical application, we choose two types of real options under two sources of uncertainties. Via thoroughly discussion with the chief manage of the company we come to believe that they are most important factors for the valuation of the new business. We pick up real options to sell nonflammable products and to establish a processing plant under a market price uncertainty and demand uncertainty. The company had recognized the importance of nonflammable products, and now ready for selling them. In addition, the manager believes that by building a new processing plant the sales of membrane ceilings can be enhanced. Considering instability of the present situation and the feasibility of options, we do not

Table 1: Risk and flexibility identification of the membrane ceilings business based on Tchankova (2002)

Basic elements	Details	Representative risks	Representative flexibility	Options
Source of risks	Physical	Delay due to natural disasters suddenly		
		Increasing demands by earthquakes suddenly	To expand production in response to sudden demand increase	To establish a processing plant
	Social	Apathetic about ceilings in Japan continuously	To combine with a new business	To start a lighting business
		Existence of new competitors	To differentiate themselves from other companies	To sell the circular membrane ceilings
	Political	Policies of Ministry of Land, Infrastructure, Transport and Tourism to membrane ceilings suddenly		
	Operational	Asking other companies to manufacture products	To manufacture in the company	To establish a processing plant
	Economic	Imports from abroad	To decreasing the import volume and frequency	To establish a processing plant
	Legal	Differences of lows between foreign countries and Japan	To quantify the strength	To built a laboratory
			To provide what is suitable in Japan	To sell the nonflammable membrane ceilings
	Cognitive	Ambiguity of the manager forecast		
Hazard factors		Growing market of membrane ceilings continuously	To prepare for equipment for a huge demand	To establish a processing plant
		Finding room for innovation	To combine with a new business	To start a lighting business
Perils		Late delivery of orders by accident		
Resources exposed to risk	Physical resource	(No dedicated stuff)		
	Human resource	More people needed as the business is spreading	To employing as a engineer or veteran or young person	To increase human resource
	Financial resource	(No impact on the entire management)		

(Blank spaces for representative flexibility mean that risks related to flexibility do not have significant effects on the business.)

select the other options; to start a lighting business, built a laboratory and increase human resource. For example,the reasons we do not choose the option to start a lighting business as follows. If the company starts the lighting business, the business increases uncertainty in spite of facing risks of the membrane ceilings business. It makes management more difficult. Then, we judge that the company should decide to start it or not after the membrane ceilings business is on track.

We expect that a nonflammable ceiling is a substitute for pre-exist products. To be precise, let x_1, x_2 and x_1' denote the demands of pre-exist products, the demands of non-flammable ceilings and the demands of pre-exist products after selling nonflammable ceilings. Then, the equation $x_1 = x_1' + x_2$ holds.

On the other hand, we expect that the company are able to get three advantages by constructing a new plant; an increase of the products, a decrease of production time and supply of the circular membrane ceilings. The plant enables the company to increase the supply of the circular membrane ceilings while the company can sell the same amount of pre-exist products and nonflammable ceilings. Hence, let x_2' denote the demands of the circular membrane ceilings, and we define total demands as $x_1' + x_2 + x_2'$. According to the feasibility evaluation by the company, the manager can exercise these options from 2017 considering feasibility. Note that to hold these options, the main business must keep generate cash-flows for the investment, and the company must cooperate with another company which makes nonflammable ceilings. Fortunately, the company already have a room for building a new plant.

3. Valuation model

In step 4, we evaluate the new business and derive the optimal exercise strategy that maximize the new business. We use three methods, that is, the NPV, Monte Carlo DCF, and real option approach.

3.1. Net Present Value Analysis

We first use the standard NPV approach as a benchmark. Data on the membrane ceilings business are provided by the company, which is summarized in Table 2. We use both given and forecast values for the NPV analysis. Estimation of the discount rate is one of the major problems in the NPV analysis. In this paper, we use comparable multiple valuation method for the estimation because the company is not a listed company.

Table 2: Data on the membrane ceilings from the owner

item
the number of matters per year
construction per matter
price per unit
percentage of demands of the added-value products
profitability
labor cost
tax rate
CAPEX
expected growth rate

(We call a combination of nonflammable membrane ceilings and circular membrane ceilings added-value ceilings.)

3.2. Monte Carlo DCF method

An advantage of the Monte Carlo DCF method is it can produce distribution of the project value in addition to the expected value. Note that unlike the real option approach, managerial decision-making is predetermined and not optimized. The real options analyzed in the study are utilized to stop a decline of the price and to offer more products. We assume that construction per matter, price per unit and percentage of demands of the added-value products in Table 2 are uncertain. We consider in this paper that the uncertainty follows a geometric Brownian motion. To estimate parameters, we apply the method of Copeland and Antikarov (2001) that uses the manager's forecasts. Estimated values for the parameters are shown in Table 3. We assume that nonflammable membrane ceilings and circular membrane ceilings are referred to as added-value ceilings, and that they are treated as the same ones for simplicity.

Table 3: Predictions of uncertainty

	2015	2016	2017	2018	2019	2020
construction per matter (m2)	16.95	19.80	23.12	27.01	31.54	36.84
upper						40.00
price of the present product per unit (JPY)	39,835	37,639	35,564	33,603	31,750	30,000
lower						29,000
price of the added-value product per unit (JPY)		50,000	59,460	70,711	84,090	100,000
upper						110,000
percentage of demands of the added-value product (%)		3	4	6	8	12
upper						15

In order to deal with the ambiguity, in the Monte Carlo DCF method, we take both estimated drifts μ and volatilities σ of four items in Table 3 are under normal laws with a mean μ and a standard deviation $a \times \mu$ and mean σ and standard deviation $b \times \sigma$, respectively, where a and b are constants This is a simple way for taking the manager's misspecification into account.

3.3. A real options approach

We explain how to assess the value of real options. The identified two options should be exercised optimally. This timing is closely related to optimal decision-making. It should be emphasized that the Monte Carlo DCF method cannot find it since it is predetermined without considering optimality. In this study, the timing and the value are calculated by the concept of a switching option. The switching option is a general option which enables to switch to other situations by paying switching costs. If the number of stages and the amounts of money are changed, it can estimate many kinds of real options. Now, its framework is applies to the membrane business. In our model, there are three stages; the present situation, a stage in selling nonflammable ceilings and a stage in building the plant. The company decides to change the stage or to stay at time t $(t = 0, 1, 2 \cdots, T)$. Furthermore, it receives the value of the stage after deciding at the time $t+1$. Let stage 0, stage1 and stage 2 denote the present situation, selling nonflammable ceilings and building the plant. The company must pay C_{01} when it switches from stage 0 to stage 1 ,and C_{12} when it switches from stage 1 to stage 2 and C_{21} when it switches from stage 2 to stage 1. C_{01}, C_{12} and C_{21} are positive. If the company pay the cost, it is able to change the stage at any time. This framework is shown as below.

Fig. 2. Stages and switching costs in the membrane business

In this paper we use a lattice method to solve a dynamic programming. We define $V_A(t, j)$, $V_B(t, j)$ and $CF(t, j)$ as the value after decision-making, the value before decision-making and cash flow of stage j at the time t, respectively. As $V_A(t, j)$ is calculated by the value at the time $t+1$, $V_A(t,j)$ is given as follows:

$$V_A(t,j) = e^{-rdt}E_t[V_B(t+1,j)], \quad (j=0,1,2), \tag{1}$$

where r is a risk-free rate and $E_t[\cdot]$ represents the expected value at the time t, which means the company receive the value if it makes optimal decisions after the timing t. First of all, we presume the company is at stage 0. In the case of stage 0, it has choices between staying at stage 0 and switching to stage 1. Therefore, because it requires to pay C_1 with switch, $V_B(t,0)$ is as follows:

$$V_B(t,0) = CF(t,0) + \max\left(V_A(t,0), V_A(t,1) - C_{01}\right). \tag{2}$$

From Equation 2, it stays at stage 0 when $V_A(t,0) \geq V_A(t,1) - C_1$ holds and it switches to stage 1 when $V_A(t,0) < V_A(t,1) - C_1$ holds.

Similarly, we assume that it is at stage 1. In the case of stage 1, it has choices between staying at stage 1 and switching to stage 2. Thus, because it requires to pay C_2 with switch, $V_B(t,1)$ is as follows:

$$V_B(t,1) = CF(t,1) + \max\left(V_A(t,1), V_A(t,2) - C_{12}\right). \tag{3}$$

From Equation 3, it stays at stage 1 when $V_A(t,1) \geq V_A(t,2) - C_{12}$ holds and it switches to stage 2 when $V_A(t,1) < V_A(t,2) - C_{12}$ holds.

In the case of stage 2, $V_B(t,2)$ is written as

$$V_B(t,2) = CF(t,2) + \max\left(V_A(t,2), V_A(t,1) - C_{21}\right). \tag{4}$$

From Equation 4, it stays at stage 2 when $V_A(t,2) \geq V_A(t,1) - C_{21}$ holds and it switches to stage 1 when $V_A(t,2) < V_A(t,1) - C_{21}$ holds.

If the value of each stage can be expressed as a lattice model, Equation 1 is calculated by backwards induction from the time T. Copeland and Antikarov (2001) shows the method that some uncertainties are combined to express the value as a lattice model. We apply the method to estimate the switching options.

Moreover, we introduce an approach to deal with ambiguity. We define ν and σ as mean and standard deviation of the growth rate of the project value for the lattice model. We assume the growth rate follows normal distribution and estimate the project value $V(c,d)$ when we change ν to $\nu+c$ and σ to $\sigma+d$. In addition, we define $R(c,d)$ as Kullback-Leibler divergence between $N(\nu,\sigma)$ and $N(\nu+c,\sigma+d)$. After we add $R(c,d)\times\theta$ to $V(c,d)$, the minimum $V(c,d)$ is the value including ambiguity.

4. Results

4.1. NPV analysis

First of all, we predict the future values of items through interviews with the owner. We estimate NPV using the values and the discount rate calculated by comparable multiple valuation method. The result is shown in Table 4.

Table 4: NPV of stage 0

	2015	2016	2017	2018	2019	2020
the number of matters per year	3	6	15	30	45	60
construction per matter (m2)	16.95	19.80	23.12	27.01	31.54	36.84
total construction (m2)	50.85	118.78	346.83	810.18	1419.39	2210.40
price of the present product per unit (JPY)	39,835	37,639	35,564	33,603	31,750	30,000
sales (JPY)	2,025,610	4,470,819	12,334,692	27,224,480	45,066,322	66,312,000
profitability (%)	50%	49%	48%	47%	46%	45%
profit (JPY)	1,012,805	2,190,701	5,920,652	12,795,506	20,730,508	29,840,400
labor cost (JPY)	7,000,000	7,500,000	8,000,000	8,500,000	9,000,000	9,500,000
tax rate (%)	42%					
CAPEX (JPY)	1,000,000	1,500,000	2,000,000	2,500,000	3,000,000	3,500,000
CF (JPY)	-6,987,195	-6,809,299	-4,079,348	-8,607	3,803,695	8,297,432
discount rate (%)	5%					
expected growth rate (%)	3%					
terminal value (JPY)						390,572,792
NPV (JPY)	294,666,889					

From Table 4, the NPV of the project is 294,666,889(JPY). Through the discussion with the owner, it is assumed that profitabiliity is decreasing and labor cost and capex are increasing gradually. The reasons are that more people are needed to proceed the increasing work and equipment, for example a showroom, is more important to spread the business quickly. Furthermore, CF is changed from negative to positive from 2019. The notable point is terminal value because it takes up a large percentage of the the project value. Thus, it is considered that the expected growth rate and the discount rate have enormous impacts on the value.

Next, we estimate NPV in the case that the company starts to selling the add-valued product in 2017.

Table 5: NPV of stage 1

	2015	2016	2017	2018	2019	2020
the number of matters per year	3	6	15	30	45	60
construction per matter (m2)	16.95	19.80	23.12	27.01	31.54	36.84
total construction (m2)	50.85	118.78	346.83	810.18	1419.39	2210.40
price of the present product per unit (JPY)	39,835	37,639	35,564	33,603	31,750	30,000
price of the added-value product per unit (JPY)		50,000	59,460	70,711	84,090	100,000
percentage of demands of the present products (%)	100%	100%	96%	94%	92%	88%
percentage of demands of the added-value product (%)		(3.00%)	4.24%	6.00%	8.49%	12.00%
sales (JPY)	2,025,610	4,470,819	12,686,329	29,028,309	51,370,020	84,879,360
profitability (%)	50%	49%	48%	47%	46%	45%
profit (JPY)	1,012,805	2,190,701	6,089,438	13,643,305	23,630,209	38,195,712
labor cost (JPY)	7,000,000	7,500,000	8,000,000	8,500,000	9,000,000	9,500,000
tax rate (%)	42%					
CAPEX (JPY)	1,000,000	1,500,000	3,000,000	2,500,000	3,000,000	3,500,000
CF (JPY)	-6,987,195	-6,809,299	-4,910,562	483,117	5,485,521	13,143,513
discount rate (%)	5%					
expected growth rate (%)	3%					
terminal value (JPY)						618,685,222
NPV (JPY)	476,011,474					

Comparing Tabel 5 to Tabel 4, it makes a big profit thanks to stage 1. Moreover, terminal value grows more two hundred million. It leads to the increase of NPV. Though changing a stage takes cost, the company should start to sell the new product immediately because of additional revenue.

Thirdly, we assess NPV in the case that the company starts to selling the add-valued product in 2017 and building the plant in 2020.

Table 6: NPV of stage 2

	2015	2016	2017	2018	2019	2020
the number of matters per year	3	6	15	30	45	60
construction per matter (m2)	16.95	19.80	23.12	27.01	31.54	36.84
total construction (m2)	50.85	118.78	346.83	810.18	1419.39	2210.40
price of the present product per unit (JPY)	39,835	37,639	35,564	33,603	31,750	30,000
price of the added-value products per unit (JPY)		50,000	59,460	70,711	84,090	100,000
percentage of demands of the present products (%)	100.00%	100.00%	95.76%	94.00%	91.51%	88.00%
percentage of demands of the added-value products (%)		(3.00%)	4.24%	6.00%	8.49%	(12.00%)
percentage of demands of the added-value product (%)		(6.00%)	(8.49%)	(12.00%)	(16.97%)	24.00%
sales (JPY)	2,025,610	4,470,819	12,686,329	29,028,309	51,370,020	111,404,160
profitability (%)	50%	49%	48%	47%	46%	45%
profit (JPY)	1,012,805	2,190,701	6,089,438	13,643,305	23,630,209	50,131,872
labor cost (JPY)	7,000,000	7,500,000	8,000,000	8,500,000	9,000,000	9,500,000
tax rate (%)	-5,987,195	-5,309,299	-1,910,562	2,983,117	8,485,521	23,566,486
CAPEX (JPY)	1,000,000	1,500,000	3,000,000	2,500,000	3,000,000	83,500,000
CF (JPY)	-6,987,195	-6,809,299	-4,910,562	483,117	5,485,521	-59,933,514
discount rate (%)	5%					
expected growth rate (%)	3%					
terminal value (JPY)						944,560,121
NPV (JPY)	671,669,607					

From Table 6, although CF of 2020 is negative due to the cost, the terminal value makes NPV higher than stage 1. Comparing sales of 2020 with that of 2019, the value is twice. Then, we recognize a powerful effect of the plant.

4.2. Monte Carlo DCF techniques

4.2.1. Base case

In this analysis, we assume that the company changes to stage 1 when 2017 starts and to stage 2 when percentage of demands of the added-value products is over 10%. It is supposed that C_1 is 1 million (JPY), C_2 is 80 million (JPY) and the number of simulation is 10 thousand. Moreover, the company can make decisions weekly. The result of Monte Carlo DCF techniques is shown as below.

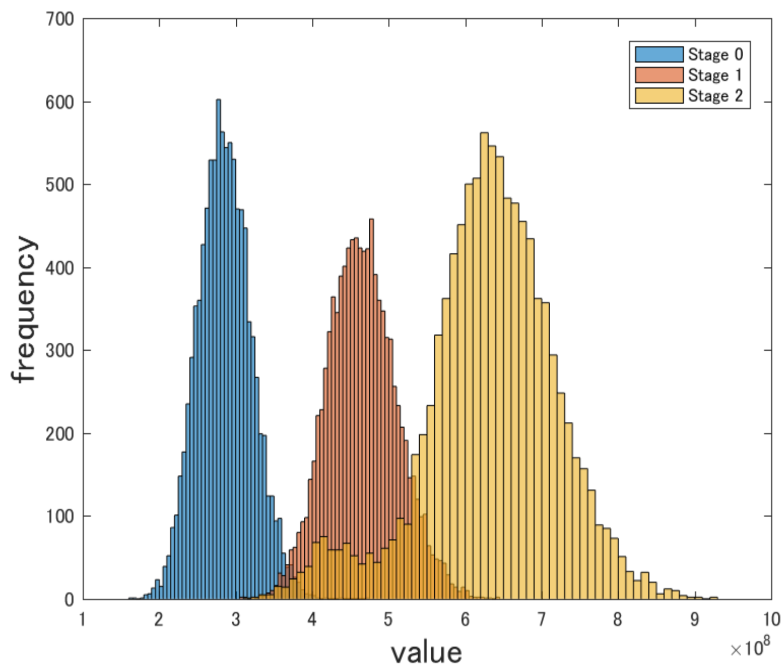

Fig. 3. Distribution of the value of each stage

From Fig. 3, NPVs of each stage are estimated as distribution. The result of Table 4 is looked as if the value of stage 1 is always higher than that of stage 0. However, there is a possibility the value is lower from Fig. 3. Similarly, it is possible that the value of stage 2 is lower than that of stage 1. In addition, the distribution of stage 2 has wide width. It means that stage 2 may produce higher value.

The results of Monte Carlo DCF Techniques can provide the owner with the width of the value. He requires to consider not only how to make a profit but also how to deal with bad situations for management. Thus, the width of the value gives a helpful suggestion about decision-making.

4.2.2. Sensitivity analysis

First, we analyze the threshold of stage 2. In Subsection 4.2.1, we assume that the threshold is 10 %. This is because we consider that the company can expect stable sales when percentage of demands of the added-value products is higher than 10 %. Anyway, we examine how the threshold impacts on the project value. The expected values and the standard deviations of each threshold are summarized in Table 7.

Table 7: The expected values and the standard deviations of each threshold of stage 2

threshold (%)	the expected values	the standard deviations
5	642,384,179	72,786,014
6	641,389,933	73,086,921
7	639,630,888	72,624,243
8	642,470,913	74,324,586
9	639,414,741	75,585,588
10	630,773,402	88,346,531
11	603,013,984	113,160,711
12	555,020,937	127,010,234

From Table 7, as threshold becomes low, the expected values tend to become high and rates of them are low. In contrast, high thresholds increase the standard deviations. Hence, the company should decide to change a stage early.

Second, as we mentioned before in Subsection 4.1, it is assumed that the expected growth rate and the discount rate make huge impacts on the project value. The expected values and the standard deviations of each the expected growth rate and the discount rate are shown in Table 8 and Table 9.

Table 8: The expected values of each stage

	expected growth rate (%)								
	0			3			5		
discount rate (%)	stage 0	stage 1	stage 2	stage 0	stage 1	stage 2	stage 0	stage 1	stage 2
5	108,510,294	184,210,982	210,846,619	285,645,982	464,597,445	631,415,183			
8	52,726,797	95,494,583	77,512,265	94,339,218	161,453,000	176,576,003	168,386,128	278,680,381	352,160,400
11	26,503,668	53,602,156	14,796,559	42,788,585	79,550,066	53,492,330	62,883,598	111,257,202	101,200,602

Table 9: The standard deviations of each stage

	expected growth rate (%)								
	0			3			5		
discount rate (%)	stage 0	stage 1	stage 2	stage 0	stage 1	stage 2	stage 0	stage 1	stage 2
5	15,076,247	19,524,955	31,215,429	35,172,693	45,985,383	86,178,937			
8	8,796,640	11,438,785	17,435,296	13,377,213	17,571,373	27,568,410	22,008,094	28,703,057	50,031,066
11	5,748,340	7,394,347	14,128,087	7,570,007	9,815,956	15,515,279	9,743,073	12,703,573	19,220,405

Table 8 indicates that differences of several percentage change the value dramatically. It is found that the relations of the standard deviations of each stage are same under any conditions in Table 9. However, the relations of the expected values of each stage are changed as the discount rate is increasing from Table 8. The reason is that the high discount rate makes it difficult to collect the switching cost. Furthermore, distribution of NPV is estimated as below when expected growth rate is 3% and discount rate is 8%.

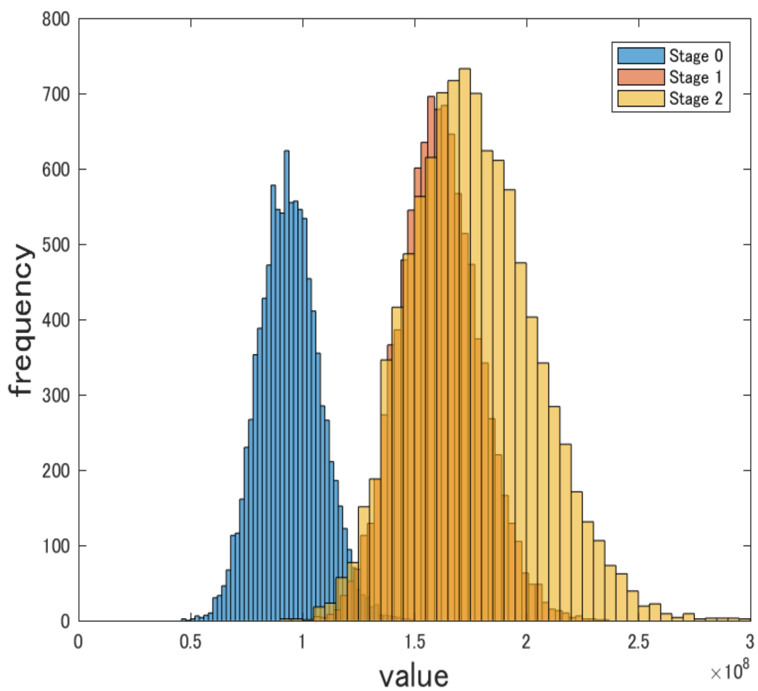

Fig. 4. Distribution of value
(expected growth rate:3% and discount rate:8%)

We can read it from Fig. 4 that there is only a little small difference between stage 1 and stage 2. It seems that this profound effects of expected growth rate and discount rate is unique to a new business. Therefore, we realize again how important estimating them is.

Third, we discuss the problem of ambiguity. Though uncertainty are expressed by the owner's forecast, he does not have complete confidence on his forecast. Thus, we try to solve the ambiguity with distribution of parameters. The rates of expected values and standard deviations are shown in the following when drift μ and volatility σ of four items in Table 3 follow normal distribution with mean μ and standard deviation $a \times \mu$ and mean σ and standard deviation $b \times \sigma$, where a and b is constant. The number of simulation path is 50 thousand.

Table 10: Rates of expected values (%) based on $a = b = 0.00$ in stage 0

		b										
		0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
a	0.00	1.0000	1.0000	0.9998	0.9998	1.0002	0.9996	0.9997	1.0003	1.0002	0.9996	0.9998
	0.05	1.0022	1.0009	1.0015	1.0026	1.0028	1.0034	1.0032	1.0007	1.0028	1.0025	1.0007
	0.10	1.0080	1.0065	1.0086	1.0055	1.0055	1.0090	1.0096	1.0088	1.0079	1.0073	1.0084
	0.15	1.0157	1.0160	1.0161	1.0176	1.0175	1.0204	1.0174	1.0181	1.0170	1.0197	1.0198
	0.20	1.0305	1.0280	1.0337	1.0323	1.0298	1.0284	1.0318	1.0302	1.0297	1.0342	1.0313
	0.25	1.0456	1.0481	1.0446	1.0505	1.0471	1.0485	1.0468	1.0500	1.0455	1.0522	1.0495

Table 11: Rates of standard deviations (%) based on $a = b = 0.00$ in stage 0

		b										
		0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
a	0.00	1.000	1.009	1.006	1.021	1.030	1.041	1.055	1.065	1.085	1.106	1.125
	0.05	1.274	1.277	1.279	1.274	1.296	1.290	1.307	1.323	1.351	1.354	1.368
	0.10	1.858	1.859	1.858	1.844	1.864	1.866	1.887	1.885	1.895	1.911	1.929
	0.15	2.553	2.553	2.546	2.559	2.573	2.563	2.569	2.579	2.597	2.612	2.627
	0.20	3.318	3.318	3.337	3.330	3.323	3.334	3.335	3.333	3.364	3.355	3.378
	0.25	4.116	4.136	4.107	4.099	4.131	4.126	4.141	4.133	4.145	4.182	4.142

Table 12: Rates of expected values (%) based on $a = b = 0.00$ in stage 1

		b										
		0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
a	0.00	1.0000	0.9998	1.0001	1.0001	1.0000	1.0003	1.0000	1.0007	1.0005	0.9999	1.0003
	0.05	1.0024	1.0019	1.0024	1.0038	1.0031	1.0044	1.0039	1.0021	1.0039	1.0034	1.0013
	0.10	1.0116	1.0103	1.0116	1.0097	1.0094	1.0120	1.0126	1.0126	1.0118	1.0105	1.0112
	0.15	1.0232	1.0243	1.0234	1.0256	1.0249	1.0271	1.0256	1.0256	1.0250	1.0269	1.0275
	0.20	1.0427	1.0429	1.0458	1.0463	1.0443	1.0425	1.0436	1.0431	1.0436	1.0478	1.0455
	0.25	1.0687	1.0685	1.0679	1.0722	1.0692	1.0697	1.0681	1.0724	1.0671	1.0730	1.0711

Table 13: Rates of standard deviations (%) based on $a = b = 0.00$ in stage 1

		b										
		0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
a	0.00	1.000	1.005	1.005	1.020	1.029	1.042	1.054	1.065	1.087	1.107	1.131
	0.05	1.291	1.293	1.299	1.295	1.306	1.309	1.327	1.340	1.372	1.373	1.383
	0.10	1.916	1.912	1.917	1.903	1.922	1.923	1.945	1.934	1.954	1.967	1.983
	0.15	2.670	2.673	2.651	2.681	2.677	2.674	2.683	2.679	2.701	2.718	2.734
	0.20	3.500	3.517	3.518	3.524	3.521	3.517	3.508	3.522	3.557	3.552	3.579
	0.25	4.422	4.425	4.443	4.400	4.427	4.424	4.429	4.436	4.448	4.478	4.455

Table 14: Rates of expected values (%) based on $a = b = 0.00$ in stage 2

		b										
		0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
a	0.00	1.0000	0.9995	0.9997	0.9999	0.9997	1.0003	0.9991	1.0002	0.9998	0.9986	0.9986
	0.05	0.9965	0.9969	0.9971	0.9993	0.9973	0.9994	0.9987	0.9973	0.9986	0.9979	0.9952
	0.10	0.9974	0.9957	0.9966	0.9956	0.9945	0.9970	0.9978	0.9990	0.9981	0.9950	0.9963
	0.15	1.0028	1.0041	1.0023	1.0060	1.0051	1.0070	1.0063	1.0050	1.0053	1.0075	1.0080
	0.20	1.0218	1.0243	1.0254	1.0276	1.0251	1.0223	1.0227	1.0234	1.0251	1.0292	1.0265
	0.25	1.0552	1.0532	1.0549	1.0576	1.0555	1.0552	1.0539	1.0587	1.0527	1.0583	1.0569

Table 15: Rates of standard deviations (%) based on $a = b = 0.00$ in stage 2

		b										
		0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
a	0.00	1.000	1.002	1.011	1.016	1.022	1.035	1.050	1.060	1.078	1.098	1.124
	0.05	1.253	1.250	1.256	1.254	1.262	1.267	1.282	1.286	1.318	1.325	1.330
	0.10	1.773	1.768	1.775	1.768	1.780	1.780	1.799	1.787	1.804	1.818	1.828
	0.15	2.378	2.384	2.362	2.390	2.380	2.380	2.390	2.384	2.397	2.409	2.424
	0.20	3.037	3.050	3.041	3.054	3.057	3.045	3.036	3.048	3.076	3.085	3.101
	0.25	3.790	3.784	3.820	3.773	3.785	3.781	3.789	3.808	3.810	3.826	3.831

From Table 10, 12 and 14, the rates of expected values are quite low for each row. In the other hand, the rates of standard deviations tend to increase gradually for each row from Table 11, 13 and 15. In spite of the same expected values, these changes of standard deviations have an impact on decision-making. Through this method, we show how much the values are changed depending on the manager's confidence possibly and decision-making is improved.

4.3. *A real options approach*

4.3.1. *Base case*

It is supposed that C_{01} is 1 million (JPY), C_{12} is 80 million (JPY) and C_{21} is 10 million (JPY). Interval between nodes is daily, and the company can make decisions weekly. We employ the binomial model to calculate the real options based on parameters in Table 16.

Table 16: Parameters of stage 0

standard deviation	0.118
discount rate	0.052
up movement level	1.006
down movement level	0.994
probability of up	0.509

Using the parameters, the values of stage 0 are shown in Table 17.

Table 17: Event tree of stage $0 (t = 0, 1, \cdots)$

t =0	1	2	3	4	5	6	7	8	9 $\cdots$
									318,977,809
								317,004,835	
							315,044,064		315,044,064
						313,095,422		313,095,422	
					311,158,832		311,158,832		311,158,832
				309,234,221		309,234,221		309,234,221	
			307,321,513		307,321,513		307,321,513		307,321,513
		305,420,637		305,420,637		305,420,637		305,420,637	
	303,531,518		303,531,518		303,531,518		303,531,518		303,531,518
301,654,084		301,654,084		301,654,084		301,654,084		301,654,084	
	299,788,262		299,788,262		299,788,262		299,788,262		299,788,262
		297,933,981		297,933,981		297,933,981		297,933,981	
			296,091,170		296,091,170		296,091,170		296,091,170
				294,259,756		294,259,756		294,259,756	
					292,439,671		292,439,671		292,439,671
						290,630,843		290,630,843	
							288,833,204		288,833,204
								287,046,683	
									285,271,213

After we calculate parameters of stage 1 and 2 like Table 16, the project values including real options are estimated in Table 18.

Table 18: $V_B(t,1)(t=0,1,\cdots)$

t =0	1	2	3	4	5	6	7	8	9 $\cdots$
									674,092,674
								670,181,352	
							666,290,506		666,377,256
						662,420,028		662,506,469	
					658,569,812		658,655,946		658,742,051
				654,739,750		654,825,579		654,911,378	
			650,929,737		651,015,262		651,100,757		651,186,225
		647,139,667		647,224,889		647,310,083		647,395,248	
	643,369,435		643,454,357		643,539,250		643,624,114		643,708,950
632,653,993		639,703,559		639,788,153		639,872,719		639,957,255	
	635,972,393		636,056,690		636,140,958		636,225,197		636,309,408
		632,344,756		632,428,729		632,512,672		632,596,587	
			628,735,928		628,819,577		628,903,198		628,986,790
				625,145,811		625,229,139		625,312,438	
					621,574,307		621,657,315		621,740,295
						618,021,321		618,104,012	
							614,486,757		614,569,131
								610,970,519	
									607,472,512

As a result, the options value is a difference between Table 18 and Table 17, that is 330,999,909(JPY). With the binomial model, we propose that the real options make the value of project over twice. Next, we show the timing of switch in Fig. 5.

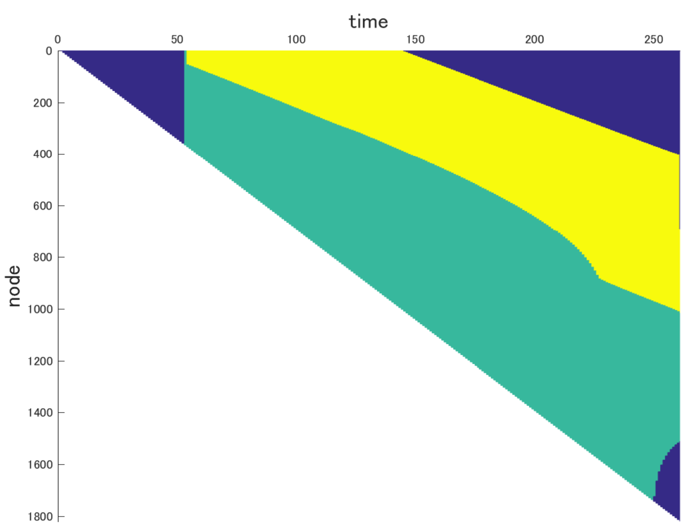

Fig. 5. The timing of switching
(blue:stage 0, green:stage 1, yellow:stage 2)

We find that stage 2 accounts for a large percentage as time goes on from Fig. 5. We assume that the company is sure that the value of changing to stage 2 with the cost is higher than that of stage 1 as t is increasing.

4.3.2. Sensitivity analysis

Next, we examine how much the expected growth rate and the discount rate have impacts on the options value. They are used to estimate probability of up and the standard deviations of event trees. The values of real options of each the expected growth rate and the discount rate are shown in Table 19.

Table 19: The expected values of each condition

	expected growth rate (%)		
discount rate (%)	0	3	5
5	83,081,569	337,796,378	
8	19,822,378	75,100,433	176,961,379
11	1,904,808	15,259,475	40,023,227

From Table 19, as the discount rate is increasing, the values are decreasing. It is considered that the reason is that the company exercises only a option of selling add-values products. However, real options add over about 5% value to the original in any cases. Thus, we find that an effect of real options is marked again.

The items of Table 16 of each stage are calculated with the approach of Copeland and Antikarov (2001). Because the values are based on the manager's forecast, we try to consider ambiguity again. As we mentioned before in Subsection 3.3, we assume the growth rate of the project value follows normal distribution and estimate the project value $V(c, d)$ when we change ν to $\nu+c$ and σ to $\sigma+d$. In addition, we define $R(c, d)$ as Kullback-Leibler divergence between $N(\nu, \sigma)$ and $N(\nu+c, \sigma+d)$. We add $R(c, d)\times\theta$ to $V(c, d)$. The minimum $V(c, d)$ is the value including ambiguity. We show change of cells of the minimum $V(c, d)$ as θ increases in Table 20.

Table 20: the cell of minimum $V(c,d)$

		c										
		-0.050	-0.045	-0.040	-0.035	-0.030	-0.025	-0.020	-0.015	-0.010	-0.005	0.000
d	-0.05	$\downarrow$										
	-0.04	$\downarrow$										
	-0.03	$\downarrow$										
	-0.02	$\downarrow$										
	-0.01	$\downarrow$										
	0.00	$\downarrow$		$\rightarrow$	$\rightarrow$	$\rightarrow$	$\rightarrow$	$\rightarrow$	$\rightarrow$	$\rightarrow$	$\rightarrow$	
	0.01	$\rightarrow$	$\nearrow$									
	0.02											
	0.03											
	0.04											
	0.05											

From Table 20, when the value of θ is low, the cells change in the column labeled $c = -0.050$. The reason is that low value of mean of the grouth rate makes the options value lower. As the value of θ becomes high, the cells change in the row labeled $d = 0.000$. It is considered that the penalty for changing standard deviation is avoided to decrease the project value. Table 20 enables us to do decision-making under ambiguity depending on the reliability of the manager's forecast.

5. Conclusion

In this paper, we estimated the value of the membrane ceilings business of the existing company including real options systematically. As a result, we indicated that it is important to apply the approach to real businesses. Moreover, we coped with ambiguity of the manager's forecast using the concept of distribution of parameters. We followed the procedure of Fig. 1 to calculate the value. We discerned risks of the project by the method of Tchankova (2002) in step 1 and searched for options for them in step 2. Specifically, we identified the options of selling add-value products and building a plant after we determined uncerntainties are prices and demands. In case studies, these two steps are paramount and we must proceed carefully. Next, we estimated the value of the project through two approaches. One is Monte Carlo DCF techniques. Unlike NPV analysis, it could express the distribution of the value and the distribution gave the owner a useful suggestion. In addition, we analyze ambiguity of the management forecast. As a concequence, we proposed that what range the ambiguity created. The other is a binomial model. The introduction of switching options enabled us to calculate the option values. Because it is a versatile method for various situations, it is suitable for a framework. We indicated that real options make the value over two times. In this model, we also dealt with ambiguity and made a proposal for sound decision-making.

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