Journal of Marine Science and Technology

Volume 13 | Issue 1 Article 7

THE DETERMINATION OF PORT FACILITIES MANAGEMENT FEE WITH GUARANTEED VOLUME USING OPTIONS PRICING MODEL

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Key words: build-and-lease contract, guarantee volume, real options, black-scholes formula.

ABSTRACT

This paper proposes a procedure to calculate the port facilities management fee (MF) in a build-and-lease (BL) contract with guaranteed volume (GV). The MF pricing problem exists in the contracts concluded by the lessees of port facilities and harbor bureaus for a long time. The problem is solved by analyzing the property of GV firstly, and then taking the real option approach to find the MF in BL contracts with GV. Finally, to demonstrate the method a real BL contract with GV is provided and its MF is calculated in this paper.

INTRDUCTION

Build-and-Lease (BL) is one of the most important approaches to operate the facilities by harbor bureaus under the port privatization policy in Taiwan.

Under the traditional leasing contracts, harbor bureaus constructed the facilities, and lessees pay annual rentals and the management fees (MF). These charges depend on what kind of facilities leased and how many volumes of traffic handled.

In the BL contracts, the harbor bureau rents a zone to the lessee and also allows the lessee to build and use necessary facilities in this zone during the contract period. The ownership of facilities constructed by the lessee, however, belongs to the harbor bureau. Instead of paying the construction cost of the facilities on lump sum basis, the harbor bureau exempts the lessee from paying the annual rental in the BL contract period. The length of such exemption is determined in such a way that all the construction costs be covered by the lessees. The length of an exemption usually is longer than 10 years because in the most cases the construction costs of port facilities are usually greater than 10 times of annual rentals.

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In order to maintain the stability of annual revenue, harbor bureaus usually require that a yearly guarantee volume (GV) be included in BL contracts. Therefore, the minimum amount of total MF a lessee has to pay in a year is equal to the GV multiplied by per unit MF stipulated in a particular contract in spite of the fact that the lessee's annual operation quantity might fall below the GV.

In view of the GV, harbor bureaus usually give a MF discount as a reward to the lessees as long as the annual volume handled exceeds GV. But there exists no exact rule or formula to determine the MF discount. The MF discount was determined case by case in practice. As a result, there might be cases in which similar contracts might have significantly different discounts. The range of MFs in BL contracts signed by Keelung, Taichung and Kaohsiung harbor bureaus in the past decades are summarized in Table 1 [5, 6, 12]. If there were no GV, MF for the same goods in the same harbor should be much similar. But, as shown in Table 1, there could be much differences between MFs in different BL contracts even they were signed by the same harbor bureau for the same cargoes handled. For example, MFs of container could have a difference of 20% of total annual lease payment in BL contracts signed by Keelung harbor bureau.

Inevitably, the differences have caused many disputes between harbor bureaus and lessees who paid higher MFs than others. As a result, the lessees used to call for a reasonable standard method to compute MF discount. Harbor bureaus are also eager to solve this problem.

In this paper Black-Scholes call option formula is applied to evaluate the value of GV engaged in a BL contract and then to derive a formula to determine the MF discount. This result can provide a consistent standard to calculate the MF discount for any level of GV.

This paper is organized into six sections. The nature of BL contract with GV will be analyzed in the next section. The reason that real option analysis (ROA) method is an appropriate approach to evaluate the value

Table 1. A summary of the MFs range in Taiwan harbor bureaus

Port	Cargoes	Min. MF	Max. MF
Keelung	cement	29 NT/ton	31 NT/ton
	liquid	26 NT/ton	30 NT/ton
	general cargo	15 NT/ton	40 NT/ton
	container	10% of total annual lease payment	30% of total annual lease payment
	construction and building	10% of total annual lease payment	30% of total annual lease payment
	oil	24NT/ton	
Taichung	Cement	20NT/ton	23 NT/ton
	liquid	21 NT/ton	23 NT/ton
	general cargo	15.7% of handling charge	18.2% of handling charge
	container	front yard°G13%~20% of sum of handling charge and equipment expense back yard: 140 NT/container	
	grain	12% of operation revenue	14% of operation revenue
	coal (general)	15 NT/ton	
	coal (TEC)	26.16 NT/ton	
	oil	17.66~30NT/m^2 or 10NT/ton	
Kaohsiung	cement	22 NT/ton	35 NT/ton
	liquid	2.1 NT/ton	61 NT/ton
	general cargo	2%~4% of operation revenue	
	container	10% of total annual lease payment	
	grain	10% of total annual lease payment	
	construction and building	10% of total annual lease payment	
	oil	11 NT/ton	
	iron	4.3 NT/ton	

Source: Statistical Abstracts 2003 of Keelung, Taichung, and Kaohsiung [5, 6, 12].

of GV will be illustrated in Section 3. In Section 4, a formula to determine the MF discount in a BL contract with a particular level of GV will be derived. Finally, a real case will be studied using the formula derived from this paper. The last section gives a brief conclusion of the present study.

THE NATURE OF BL CONTRACT WITH GV

Under the traditional contract, harbor bureau might invest by itself, say, C_0, to build the necessary facilities for leasing. Assuming that there is no technology advantage to lessee to build the facilities, the lessee also has to spend C_0 to build them. Hence, we can assume that, in a BL contract, the present value of the sum of annual rentals paid by the lessee to the harbor bureau must also be C_0. Otherwise the contract should not be concluded.

Let R_t be the total rental of year t under a BL contract. It is also assumed that R_t is also the harbor bureau's annual amortization of facilities construction cost. Moreover, let r be the cost of capital of the lessee. Under the assumption of value maximization objective of harbor bureau [9], the BL contract period, T, can be determined by the following equation:

$$C_0 = \sum_{t=1}^{T} \frac{R_t}{(1+r)^t} \qquad (1)$$

Based on the theory of capital budgeting, the value of a project can be represented by the net present value (NPV) of the incremental free cashes created by this project. The free cash flow is defined as [3]:

Free cash flow

= Earning before interest and taxes (EBIT)

– Cash taxes on EBIT + Incremental accrued taxes

+ Depreciation − Capital expenditures

– Incremental operating working capital (2)

Without loss of generality, it is assumed that T is an integer and

$$MF_t = MF_0 + P_t \times Q_t \tag{3}$$

where MF_0 is a constant, and P_t is the MF per handling unit of year t. If MF_t does not depend on the volume of cargo, is equal to 0. To simplify, it is also assumed that there are no side effects on the other revenues of the harbor bureau and no accrued taxes. Because harbor bureau does not have to pay income tax, and because there is no reason to believe that depreciations, incremental working capitals and additional capital expenditures are different in different BL contracts and in traditional contracts, within these T periods, the annual free cash flow coming from a BL contract can be expressed as follows:

Free cash flow$_t$

= Rental$_t$

− Amortization of facilities construction cost$_t$

+ MF_t

= $R_t - R_t + MF_t$

= MF_t

= $MF_0 + P_t \times Q_t$ (4)

for all t = 1, 2, ..., T, where (rental$_t$ − amortization of facilities construction cost$_t$) is considered as the EBIT of this contract. Hence, the value of this contract can be determined by calculating the Net Present value (NPV) of MF_t. That is, NPVMF

$$NPVMF = \sum_{t=1}^{T} \frac{MF_0}{(1+r_f)^t} + \sum_{t=1}^{T} \frac{E(P_t \times Q_t)}{(1+r_p)^t}$$

$$= MF_0 \times \frac{1}{r_f}\left[1 - \frac{1}{(1+r_f)^T}\right] + \sum_{t=1}^{T} \frac{E(P_t \times Q_t)}{(1+r_p)^t} \tag{5}$$

where r_f is the risk-free interest rate with constant MF_0, is an appropriate risky interest rate depending on the intrinsic risk of $P_t \times Q_t$ [9], and $E(\bullet)$ is the notation of expectation operation.

In a BL contract with GV, let be the GV_t of the year t, then the free cash flow of the year t becomes:

Free cash flow$_t$

= $\max\{MF_t, GV_t \times P_t\}$

= $\max\{MF_0 + P_t \times Q, GV_t \times P_t\}$

= $MF_0 + \max\{0, (GV_t - Q_t) \times P_t - MF_0\}$ (6)

which is different from equation (4).

REAL OPTIONS

Since GV in a BL contract reduces the contract risk involved by harbor bureau, the traditional discounted cash flow (DCF) approaches to the appraisal of capital investment project, such as equation (4), can not properly capture the characteristics of this problem. GV gives harbor bureau the right to “sell” the annual MFt and receive the guaranteed revenue of $GV_t \times P_t$. If MF_t is greater than $GV_t \times P_t$, the value of GV would be worthless and harbor bureau has the same annual payments whether they have BL contract with or without GV. Otherwise it would be worthy of $GV_t \times P_t - MF_t$ which is greater than 0. So the value provided by GV would be positive. Hence,

The value of BL contract with GV

= Value of BL contract without GV

+ Value of GV (7)

Several techniques are available for evaluating the value of GV. They are, for example, NPV, Decision Tree Analysis (DTA), Real Options Analysis (ROA), etc. However, Copeland and Antikarov [4] considered that NPV can not capture the value of flexibility in management. McDonald and Siegel [8] and Trigeorgis [13] showed their examples that NPV rule always underestimates the value of investment projects when they involve managerial flexibility. Trigeorgis also mentioned that DTA rule could not adjust the discount rate to reflect the change of risk in projects. Unlike NPV and DTA, real options analysis (ROA) can be stated that the value of the project resulting from ROA already includes the value of option due to uncertainty and flexibility in management.

ROA is a systematic and integrated decision analysis process used to evaluate the investment project with managerial flexibility. It is the technique that extends from the financial option theory, which is adopted in the stock market, to be applied in real investment.

Currently, ROA is already accepted as an evaluation process for project under uncertainty in various fields. For example, Pichayapan, Kishi, Hino and Satoh [11] used ROA to evaluate the expressway projects in Hokkaido, Japan. McCormeck and Sick [7] adopted ROA for valuing undeveloped reserves in oil and gas industry. Yamagushi, Takezawa and Sumita [14] used ROA to analyze the land development in Tokyo. Concas, Glaesel, Reich and Yelds [2] valued the economic impact of transportation research activities using ROA approach. Brand, Mehndiratta and Parody [1] used ROA to analyze the risk in transportation planning.

However, there has been a lack of study applying ROA in the port planning and management field yet. On the other hand, researches on the problem of pricing MF or related port facilities have not found either except the fact that the formula of DCF has always been used by harbor bureaus to evaluate various projects in practice. Because that when GV exists in a BL contract, the annual cash flows and its risk, and therefore its discount rate of this contract will be different from that of a traditional contract. These changes can not be reflected in the traditional DCF and DTA methods. Real option method considers the changes of annual cash flows in its cash flow equation (6), and uses the risk-free rate of returns as its discount rate to solve the problem of changing discount rates.

By means of real options, a value is assigned to the options at the management's disposal, GV. This GV value can be determined in a manner that is similar to the valuation techniques for financial options. A summary of the models for option valuation is described by Mun [10]. The real option problem can be solved by solving the partial differential equation (for example, the Black and Scholes model), by dynamic programming (for example, the binomial option model) or by simulation (for example, Monte Carlo simulation). As a general rule, binomial trees are frequently applied in real option valuation, as they allow simultaneous valuation of various options and put less restrictions on the distribution of the underlying value [6].

DETERMINATION OF MF IN A BL CONTRACT WITH GV

In the problem of GV evaluation, usually the annual unit MF, P_t, is taken as a constant in the whole contract period, that is, $P_t = P_0$, for all t in the contract period. Because GV_t in BL contract is irrecoverable and is known at the beginning of the contract, and the exercise price of the put harbor bureau obtained is fixed, the value of GV_t can be evaluated by European put formula [13]:

$$p(S, t) = Xe^{-r_f t}N(-d_2) - SN(-d_1) \tag{8}$$

$$d_1 = \frac{\ln \frac{S}{X} + \left(r + \frac{\sigma}{2}\right) t}{\sigma\sqrt{t}}, \quad d_2 = d_1 - \sigma\sqrt{t}$$

where

p = price of the put
S = price of underlying asset
X = exercise price
r_f = risk-free interest rate
t = time to maturity of the option in years
σ = standard deviation of the annualized continuously compounded rate of return on the underlying asset
ln = natural logarithm
e = the base of the natural log function
$N(d)$ = the probability that a value draw randomly from a standard normal distribution will less than d

In the case of GV valuation problem,

p = value of GV_t
$S = Q_0 \times P_0$
= the facilities rent at the point of time when the contract is arranged
$X = GV_t \times P_0$
r_f = ln (1 + the average annual interest rated of bank loan)
t = time to the evaluated years
σ = standard deviation of the annualized continuously compounded rate of return on that can be calculated by:

$$\sigma = \ln(u) \tag{9}$$

Let sp be the NPV of GV, it is the value that the lessee offers to harbor bureau and is fair to be paid to the lessee by harbor bureau. Hence the NPV of MF to harbor bureau in a BL contract with GV should be equal to NPVMF – sp, say v. Let p^* be the unit MF in a BL contract with GV, the following two formulas can be obtained:

Formula 1.

The unit MF in a BL contract with GV

$$P^* = \frac{v}{A + B - C} \quad (10)$$

where

$$A = \left[\sum_{t=1}^{T}\left(\frac{GV_t}{(1+r_f)^t}\right)\right],$$

$$B = \sum_{t=1}^{T} Q_0 \times N(d_1),$$

$$C = \sum_{t=1}^{T} GV_t \times e^{-r'f\,t} N(d_2) \text{ and,}$$

$$r'_f = \ln(1 + r_f),$$

makes the value of MF in the BL contract equal to v with annual GV_t and a geometric operation quantity Q_t having a value Q_0, at the beginning of contract period with an up movement factor $u > 1$.

Proof. Because of the requirement of annual GV_t, the annual MF can be written as

$$\text{Max}\{GV_t \times P^*, Q_t \times P^*\}$$

$$= GV_t \times P^* + \text{Max}\{0, Q_t \times P^* - GV_t \times P^*\}$$

$$t = 1, 2, \ldots, T.$$

The first term in the right-hand side of the above equation stipulated at the beginning of the contract period should be treated as a riskless asset. Its NPV can be computed as follows:

$$\text{NPV}(GV_t \times P^*)$$

$$= \frac{GV_t \times P^*}{(1+r_f)^t}.$$

The second term can be treated as a call option with underlying asset $Q_t \times P^*$ and exercise price $GV_t \times P^*$, under the assumptions of Q_t having a value Q_0 at the beginning of contract period with an up movement factor $u > 1$. This term can be evaluated by Black-Scholes' European call option formula as follows: [13]

$$C_t = \text{value of Max}\{0, Q_t \times P^* - GV_t \times P^*\}$$

$$= SN(d_1) - Xe^{-r'f\,t} N(d_2) \quad (2)$$

where

$$S = Q_0 \times P^*$$

$$X = GV_t \times P^*$$

$$d_1 = \frac{\ln\dfrac{Q_0}{GV_t} + \left(r'f + \dfrac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$

σ = standard deviation of the annualized continuously compounded rate of return on $Q_t \times P^*$ that can be calculated by $\sigma = \ln(u)$

$r'_f = \ln(1 + r_f)$

$N(d)$ = the probability that a random draw from a standard normal distribution will less than d

Therefore,

$$v = \sum_{t=1}^{T} Max\{GV_t \times P^*, Q_t \times P^*\}$$

$$= \sum_{t=1}^{T} \frac{GV_t P^*}{(1+r_f)^t} + \sum_{t=1}^{T}(Q_0 \times P^*) N(d_1)$$

$$- \sum_{t=1}^{T} GV_t \times P^* \times e^{-r'f\,t} N(d_2)$$

$$= P^* \times (A + B - C)$$

where

$$A = \left[\sum_{t=1}^{T}\left(\frac{GV_t}{(1+r_f)^t}\right)\right],$$

$$B = \sum_{t=1}^{T} Q_0 \times N(d_1), \text{ and}$$

$$C = \sum_{t=1}^{T} GV_t \times e^{-r'f\,t} N(d_2).$$

This implies that

$$P^* = \frac{v}{A + B - C} \quad \text{Q.E.D.}$$

Formula 2.

Under the same assumptions made in Formula 1, the following result can be derived:

$$MFD = \frac{P^*}{P_0}.$$

A CASE STUDY

To demonstrate the method proposed in the above section, a real case of contract concluded by a shipping company, say Company A, and Taichung Harbor Bureau on July 1, 2000 is provided below. [12] Currently, the facilities' charge calculation method used by Taichung Harbor Bureau is arbitrary. That is, there exists no rule to determine how large the MFD should be offered to the facilities lessee when a contract includes a GV agreement. Hence, instead of presenting the complete contents of the contract, only the basic information related to the evaluation of the value of GV is described.

In this contract, it was arranged that Company A was responsible for building facilities, composed of a wharf, three silos, road, and digging a water way. Their costs were NT$ 300,000 thousands, NT$ 941,170 thousands, NT$ 13,667 thousands, and NT$ 84,000 thousands, respectively. The total construction cost is NT$ 1,338,837 thousands. The items of annual lease payments are listed in Table 2.

The total annual lease payment was NT$ 197,919 thousands. It was estimated that the first year operation quantity would be 1,000,000 tons and GV was also 1,000,000 tons. The unit price of MF was NT$ 37 per ton in the contracts without GV. Both parties agreed that the discounted rate of harbor bureau was 8%, the cost of capital for Company A was 10% and the unit price was fixed in the contract period.

Based on the procedure proposed in previous section, it is necessary to calculate the contract period, T, by equation (1) and estimate the volatility of annual operation quantity, Q_t. In this case, C_0 = NT$ 1,338,837 thousands, R_t = NT$ 197,919 Thousands, and r = 10%. By solving equation (1), T = 11.8 years is obtained.

Suppose that Company A and Taichung Harbor Bureau agreed that the operation quantity model can be represented by

$$E(Q_t) = Q_{t-1}e^{rQ_t}, \tag{12}$$

and also suppose that both parties agreed that the operation quantities are expected to grow on average at a constant rate of 6% and with 95% confidence, the actual operation quantity would not be below the current level for the next 11.8 years. Based on these estimates the value of the operation quantity volatility can be derived by the following equation:

$$\hat{\sigma} = \frac{\sum_{i=1}^{T} \hat{\rho}_i - \ln\left(\frac{Q_T^{lower}}{Q_0}\right)}{2\sqrt{T}} \tag{13}$$

where $\hat{\rho}_i$, i = 1, 2, ..., T, are the expected growth rates, and Q_t^{lower} is the lower 95th percentile value of Q_t. Substituting the above estimates into equation (13), we have

$$\hat{\sigma} = \frac{10.8 \times 0.06 - \ln\frac{1000000}{1000000}}{2\sqrt{10.8}} = 0.099$$

If the average risk-free interest rate is 5%, then $r'f$ = 0.049. Substituting these parameters to equation (8), we obtain the annual present values of GV for the next 11.8 years listed in Table 3.

The total present value of GV in this contract, sp, is NT$ 6,838 thousands. It is noted that the value almost comes from the first year. This fact can be easily realized because, when the time passes, the operation quantity is expected to increase so that the probability that operation quantity less than the level of GV becomes very small.

On the other hand, the value, c, is increasing when the time interval becomes longer and longer. The total amount $B - C$ is NT$ 3,410 thousands. The value of A is equal to NT$ 8,729 thousands. The NPVMF of this contract is NT$ 347,390 thousands calculated by equation (5) if GV agreement was not contained in this contract. Subtracting sp from this value, v = NT$ 340,550 thousands is obtained. Hence,

$$P^* = \frac{v}{A + B - C} = 28.1 \text{ (NT\$)}$$

and

MFD = 28.1/37 = 0.76.

CONCLUSION

The disputes between port facilities lessees and four harbor bureaus in Taiwan with respect to MF in the

Table 2. Annual lease payments included in the case study BL contract

Rent of wharf	NT$ 30,000 (thousands)
Rent of silos	94,117
Rent of road built	1,367
Rent of land	8,495
Maintenance expenses	35,211
Insurance expenses	13,209
Other expenses	15,520
Total	NT$ 197,919 (thousands)

Source: A BL contract concluded by Company A and Taichung Harbor Bureau, 2000.

Table 3. Annual NPV of GV

unit: NT$ 1,000

t	1	2	3	4	5	6	7	8	9	10	11	11.8	total
d_1	0.50	1.14	1.56	1.90	2.19	2.45	2.69	2.90	3.10	3.29	3.46	3.61	
d_2	0.00	1.00	1.39	1.70	1.97	2.21	2.43	2.62	2.8	2.97	3.13	3.27	
p	6197.5	333	151.7	81.4	33.3	33.3	2.96	1.48	1.48	1.48	0.37	0.37	6838
c	215	112	151	189	226	262	297	331	363	392	422	450	3410

BL contracts with GV have been prevailing for a long time. Although this issue has been discussed for long time, the resolution to the problem has not been found yet. In this paper, real options approach was used to analyze the problem and a procedure was proposed to evaluate MF in BL contracts with GV. The first step in the procedure is to evaluate the value of MF and NPVMF in the contract by the traditional discounted cash flow method as if it was a BL contract without GV. After that, the property of GV was analyzed and found that GV offered by the lessee to harbor bureau resembles the fact that harbor bureau gets a put option from facilities lessee. Hence, it is suitable to use Black-Scholes put formula to evaluate the value of GV, *sp*. Moreover, the value of a BL contract with GV should be equal to NPVMF – *sp*.

Next, it was pointed out that the cash flows in a BL contract with GV is the same as the cash flows that could be gotten from buying a constant annuities and a call option. In this point of view, Black-Scholes call formula was applied, and the calculation formulas of P^* and MFD were derived.

Finally, a real case of contract was investigated and its MF was calculated using the proposed method. It was found that the final MF calculated by **Formula 1** was NT$ 28.1 per ton, which is only 76 percent of the original MF of NT$ 37 per ton.

The real options method applies financial options theory to quantify the value of management flexibility under the condition of uncertainty. This method was applied in various fields successfully. In this paper an academic reasoning why this method can be applied to pricing MF for a BL contract with GV was explained and the pricing formula based on this method was successfully derived.

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