INVESTMENT EVALUATION OF TRANSPORTATION INFRASTRUTURE PROJECTS USING BINOMIAL REAL OPTION MODEL

Qiyu Qian[1], Xueqing Wang[2] and Charles Y.J. Cheah[3]
[1, 3] School of Civil and Environmental Engineering, Nanyang Technological University, Singapore.
[2] Department of Construction Management, Tianjin University, P.R. China.

Abstract

Transportation infrastructure is critical to economic growth of a country such as China. Careful evaluation of investments in traffic infrastructure projects is therefore pertinent. As traditional evaluation methods do not consider the uncertainty of future cash flows and mobility during project execution, the real option approach is gradually gaining recognition in the context of valuing construction and infrastructure projects. However, many of the cases only evaluate individual options separately although multiple options often exist in a typical large infrastructure project. Using a highway project in China as a case study, this paper first evaluates a deferment option and a growth option embedded in the project. Subsequently, the values are combined using the fuzzy analytical hierarchy process. It is found that the combined value is less than the sum of the two option values. This finding is consistent with the theoretical observations given in past real option literature despite the use of a different approach.

Keywords: Managerial flexibility, multiple real options, project uncertainty, transportation infrastructure systems.

1. Introduction

Proper and efficient functioning of a modern economy relies on the speed or quality of human capital flow, material flow, energy flow, information flow and monetary flow. Transportation infrastructure systems directly support the material flow and indirectly influence the quality and speed of the others in one way or another. In general, the systems would include railways, highways, waterways, aviation and pipelines. Urban transportation system directly affects the quality of life of city dwellers, while intercity connections dictate the pace of growth of a particular region.

Most investors in transportation infrastructure systems expect a return-on-investment commensurate with the risk of a project. Even when a project is entirely funded by the public sector, a cost-benefit analysis is usually conducted to capture all tangible and intangible social costs and benefits with the use of shadow pricing. For a transportation infrastructure procured on a BOT (Build-Operate-Transfer) or PPP (Public-private Partnership) basis, it is necessary to charge tolls and the investment evaluation of these projects are typically more challenging in view of the following factors:

I) Market uncertainty

For a transportation infrastructure project that collects revenue based on toll charges, the market uncertainty is primarily attributed to two factors: traffic volume and 'acceptable' rates of toll charges. The traffic volume is affected by the level of economic activities in the region, number of cars, fuel prices, weather, commuters' preferred modes of transport, competing routes etc. On the other hand, the rates of toll charges would generally be associated with the income level of road users, significance of the proposed project to regional economic growth, traffic volume, modes and costs of financing and operating and maintenance costs. Obviously, whether the rates are deemed 'acceptable' would also depend on non-economic factors such as politics.

II) Cost uncertainty

Both the capital expenditure and operating and maintenance costs are subjected to inflation in terms of material costs and wages. Major rehabilitations, which may be planned many years after initial completion, pose further uncertainty in the future.

III) Uncertainty in government regulations

Due to the critical role that a transportation infrastructure system plays in a regional economy, the government often maintains a 'hidden' hand in moderating the toll rates through its regulatory power. In emerging countries, people sometimes view all transportation systems, including toll roads, as public goods or expect the government to subsidize the road users' costs. Alternatively, the government may grant rights to other project promoters to build competing routes.

Due to the presence of the above uncertainty factors, flexibility measures are commonly introduced in the planning, design and execution of transportation infrastructure projects. Such flexibility measures can be often viewed as a form of real options and the methodology of option valuation can be applied with proper adjustments [1,2]. Two common examples include deferment option (e.g., ability to delay the start of a project) and expansion option (e.g., ability to build more lanes when traffic volume increases). In addition, to attract foreign investors, some government of the emerging countries may provide guarantees on toll revenues or minimum level of traffic volume, which are actually a form of real option [3]. The values of these options need to be captured during the course of evaluating the prospects of investment.

2. Literature Review

The use of option pricing techniques to evaluate real assets is not new to many industries. Nevertheless, in the context of construction and infrastructure projects, literature written on this topic remains limited. In addition most of the literature focused only on the evaluation of individual options in isolation, even though more than one option is usually found in a typical infrastructure project. For example, Cheah and Liu [4] evaluated a series of options in the Dabhol Power Plant project in India. However, they continued to comment that:

> "…it is technically incorrect to simply sum up all the option values together due to two reasons. First, interactions exist among these options. For instance, once the abandonment option of selling the plant is exercised, the expansion option

> would no longer exist. Second, different options are "owned" by different parties; therefore options should be assessed and consolidated only if they belong to the same party concerned."

A seminal work on valuation of investments with multiple real options is given by Trigeorgis [5]. The paper studies the nature of option interactions and the valuation of capital budgeting projects possessing flexibility in the form of multiple real options. Upfront, Trigeorgis emphasized that option interactions can be small or large, negative or positive, and generally depend on the type, separation, degree of being "in the money" and the order of the options involved. Through a generic example that contains a deferment, abandonment, contraction, expansion and switching option, he concluded that when two options are of opposite type (e.g. a put and a call), interactions are small and the separate option values are approximately additive. This is because the conditional probability of exercising the latter option given prior exercise of the former would be small. Based on Cheah and Liu's comments quoted earlier, the conditional probability of exercising the expansion option (a call) when the former abandonment option (a put) has been exercised is effectively zero and the value of the two options is exactly additive.

When interactions are significant, valuation of multiple real options becomes complex. Trigeorgis [5] made use of a log-transformed version of binomial numerical analysis that he developed earlier [6]. Essentially, his approach entails valuation of multiple options *implicitly*. In this paper, the fuzzy analytical hierarchy process is proposed as an alternative approach to combine the value of multiple options *explicitly*. Although this approach is more subjective than implicit valuation, it is much simpler to apply since the valuation of separate options can proceed in isolation prior to combination.

2.1 Fuzzy analytical hierarchy process

The procedure of the fuzzy analytical hierarchy process may be outlined as follows:

i. Assume that there are a total of $\boldsymbol{l}$ real options that exist in a project. Evaluate the value of each option $\mathbf{V}_j$, $\boldsymbol{j} \in \{1, 2, \ldots, \boldsymbol{l}\}$, using an appropriate real option evaluation methodology without considering any effects of interaction.

ii. Identify a finite set of factors **U** that may influence the value of options $\mathbf{V}_j$ <u>due to the effects of interaction</u>. These factors may include, for example, the order of the options, overlapping duration between maturity periods, positive/negative influence on other options, likelihood of exercise, or significance of options at the broader level of corporate strategy of the option owner. Let each factor be denoted as $\mathbf{U}_k$ and assume that there are a total of $\boldsymbol{m}$ factors, then

$$\mathbf{U} = \{ \mathrm{U}_1, \mathrm{U}_2, \ldots\ldots.., \mathrm{U}_m\};\ \boldsymbol{k} \in \{1, 2, \ldots, \boldsymbol{m}\}$$

iii. Subsequently, expert opinions are solicited for each of these factors based on a reverse scale of [0,1] – if a chosen factor has little effect on the option value arising from interaction, the value would be close to 1 (and vice versa). Suppose there are a total of $\boldsymbol{n}$ experts or valuators. Each valuator $\boldsymbol{i} \in \{1, 2, \ldots, \boldsymbol{n}\}$would evaluate the influential power of each factor $\mathbf{U}_k$, with their opinion conveniently summarized in a matrix form:

$$R_j = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & r_{ik} & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}_j, j \in \{1, \cdots, l\}$$

where r_{ik} represents the opinion given by valuator i on factor $\mathbf{U}_k$. The matrix essentially captures the "fuzziness" of opinion concerning the effects of interaction. This exercise is repeated for each of the option so there will be a total of l matrices of R.

iv. The relative importance of each factor $\mathbf{U}_k$ (in the context of evaluating the combined option) is then represented by its associated weighting $\mathbf{W}_k$:

$$\mathbf{W} = \{ W_1, W_2, \ldots\ldots, W_m \}, \sum_{k=1}^{m} W_k = 1$$

v. Compute the combined weighting $\mathbf{B}_j$ through multiplication:

$$\mathbf{B}_j = W \circ R_j^T = [W_1, W_2, \cdots, W_m] \circ \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & r_{ik} & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}_j^T = \{ b_1, b_2, \ldots\ldots, b_n \}$$

vi. Naturally, the experts/valuators would have different background, e.g., years of experience in the field. Therefore, the reliability and accuracy of their opinion would also differ. The relative merits of expert opinions can be represented by associating a weighting $\mathbf{E}_i$ for each valuator i :

$$\mathbf{E} = \{ E_1, E_2, \ldots\ldots\ldots, E_n \}, \sum_{i=1}^{n} E_i = 1$$

vii. The "fuzzy multiplier" f_j for each option $\mathbf{V}_j$ is:

$$f_j = E \circ B_j^T = [E_1, E_2, \cdots, E_n] \circ \begin{bmatrix} b_1 \\ \vdots \\ b_n \end{bmatrix}, \ j \in \{1, 2, \ldots, l\}$$

viii. Finally, the combined value of multiple options is:

$$\mathbf{V}_{\mathbf{total}} = \sum_{j=1}^{l} f_j V_j$$

3. Case Study

In this section, a case study is used to illustrate: (1) the evaluation of two call options using the standard binomial tree approach; (2) an alternative approach to combine the values of these two options explicitly, instead of evaluating them implicitly following a more complex method such as Trigeorgis' log-transformed binomial numerical analysis method [6]. The case chosen is a highway project located in China, which will be referred as "JS Highway" for simplicity.

3.1 Background of case

The transportation infrastructure system in China is under tremendous stress to keep up with development in the country. The network intensity of roads in China, as measured by length of road per square km of land, is only about 0.12; such level of intensity is about 1/5 of that of the United States, 1/14 of Germany's, and 1/24 of Japan's.

The JS Highway project was proposed back in the mid-1990s to promote economic growth for one of the major cities in the east. The project was planned to undergo two phases of construction. Phase I would start in 1997, spanning a period of 3 years, which covers all foundation and pavement works. Although the highway was designed to have 6 lanes in total, only the 4 outer lanes would be paved initially, with the inner two lanes being reserved as a "green zone". Phase II would take place two years upon completion of Phase I, which then converts the reserved "green zone" into two additional lanes of highway.

The project was funded as a sino-foreign joint venture that lasts until 2020. The foreign investors were allowed to purchase a portion of the equity and able to recoup their returns based on cash flow distribution rights as specified in the contract. The total cost of the project was approximately RMB 1.1 billion for Phase I, which was funded with 40% equity and 60% debt. In addition, about RMB 15 million was incurred in 2001 for the addition of safety infrastructures, and RMB 248 million in 2002 for the Phase II conversion. The breakdown of the capital expenditure is given in Table 1.

Year	1997	1998	1999	2001	2002
CAPEX	214.3	441.8	443.9	14.9	248.0

Table 1: Capital Expenditure (in RMB million)

Based on the past data on planning for similar projects, annual operating and maintenance expenses (with inflation) can be estimated. The highway would require major rehabilitation works in 2007, 2013 and 2018. Toll charges for the highway are categorized into five classes. By estimating the daily traffic volume and average mileage for each class, the total annual revenue is obtained.

3.2 Cost of capital

The Capital Asset Pricing Model (Sharp) is commonly used to estimate the required return-on-equity (r_e):

$$r_e = r_f + \beta_e * (r_m - r_f)$$

To get an appropriate value for β_e , five toll road operators, whose shares are publicly traded in China, were identified as proxies. After adjusting for differences in leverage, β_e is estimated as 1.475. The yield of 5-year government bonds, which was about 5%, is used to represent the risk-free rate, r_f . The value of domestic stock market index spanning 1995-2002 is used to determine an average market return r_m of 9.7%.

Based on the above assumptions and data, r_e is determined as 11.93%. When this is applied to discount the Free Cash Flow to Equity (FCFE), the Net Present Value for the JS Highway project is RMB 533.11 million.

3.3 Real option evaluation

The fact that the project is divided into two phases of execution naturally creates some flexibility in execution. When Phase I is completed and the project enters into the operating stage, the traffic and economic condition of the project becomes clearer. This provides knowledge to decide whether Phase II should be implemented or not. Put differently, a growth option exists for the execution of Phase II. In addition, it would also be of interest to assess the value of deferring the project by 1 year, since this is the time when the project company faces the highest level of uncertainty. Both the growth option and deferment option are common forms of call options, which have been widely discussed in past literature [7]. In the subsequent sections, these options are first evaluated separately, before combining their values using the FAHP method. Thus, when assessing the deferment option, only Phase I would be considered; Phase II is taken into account only when the growth option is evaluated.

3.3.1 Deferment option

If the project can be deferred by up to 1 year, this would represent an American call option with a time to maturity T = 1. The interest rate for 1-year treasury bill in China, r_f , was about 4.2% during the initial period of the project. The exercise price of this option, X, can be represented by the present value of capital expenditure of Phase I incurred during 1997-1999. The underlying asset value, S, will be the present value of the free cash flows obtained during 2000-2020, which are summarized in Table 2. Using the data from Table 1 and 2, S = 1,521.03 million; X = 1,395.66 million.

Year	Free Cash Flows	Year	Free Cash Flows	Year	Free Cash Flows	Year	Free Cash Flows
2000	33.90	2005	146.54	2010	309.11	2015	453.73
2001	41.83	2006	182.18	2011	339.18	2016	479.61
2002	80.05	2007	144.29	2012	367.93	2017	497.72
2003	101.05	2008	248.36	2013	315.59	2018	409.83
2004	174.45	2009	278.29	2014	425.23	2019	515.35
						2020	530.04

Table 2: Annual Cash Flows for Assessing Asset Value S (in RMB millions)

The estimation of volatility, σ, is always a subjective matter, but a range of 20%-40% have been adopted in the past literature. Since this highway is located within a major economic region, the volatility of cash flows is likely to be at the lower end; hence σ = 20% is assumed.

There is usually a shortfall between the equilibrium total expected rate of return of a similar-risk traded financial asset and the actual expected return of a nontraded real asset. This is conventionally denoted as δ, which captures any proportional cash flow (dividend-like) payout on the operating project. In this case, δ may be estimated as:

$$\delta = \frac{V_0 - V_1}{V_0}$$

where: V_0 is the value of underlying at present time (= 1,521.03 million);
V_1 is the value of the same underlying after 1 year, assuming that market conditions remain unchanged. This can be estimated by discounted the same set of cash flows in Table 2, except that the timing for each cash flow is delayed by 1 year.

Without illustrating the details, δ is estimated as 8.6%. With all these information, the basic parameters for constructing a binomial tree model can be computed. Here, a 5-step model will be constructed, hence $\Delta t = 1/5 = 0.2$ years. Then,

The upward movement factor, $u = e^{\sigma\sqrt{\Delta t}} = 1.094$

The downward movement factor, $d = 1 / u = 0.914$

The risk-neutral probability factor, $p = \dfrac{e^{(r_f - \delta)\Delta t} - d}{u - d} = 0.429$

The binomial tree for the underlying asset value S is depicted in Figure 1:

1,521.02	1,663.99	1,820.41	1,991.53	2,178.73	2,383.54
	1,390.21	1,520.89	1,663.85	1,820.26	1,991.36
		1,270.65	1,390.09	1,520.76	1,663.72
			1,161.38	1,270.54	1,389.97
				1,061.49	1,161.28
					970.21
t=0	t=0.2	t=0.4	t=0.6	t=0.8	t=1.0

Figure 1: Binomial Tree of Underlying Asset Value for Deferment (in RMB million)

The binomial tree for evaluating the deferment option can then be derived from Figure 1 by comparing the value of S at maturity against X and then discounted backwards:

113.65	200.33	334.49	513.84	731.09	987.88
	57.47	115.29	220.68	391.05	595.70
		18.55	45.18	110.05	268.06
			0.00	0.00	0.00
				0.00	0.00
					0.00

Figure 2: Binomial Tree of Deferment Option (in RMB million)

In Figure 2, the value of deferment option (by 1 year) is RMB 113.65 million.

3.3.2 Growth (expansion) option

As elaborated earlier, Phase II (which involves the conversion of the reserved "green zone" into two inner lanes of highway) need not be implemented if the traffic and economic conditions do not justify doing so. Effectively, Phase II is an expansion option, with a maturity period of 5 years (after 1997). The underlying asset value would be the present value of free cash flows in Phase II. The exercise price would be the capital expenditure required to implement Phase II. The rate of shortfall ("dividend-like" payout) δ would be the opportunity cost of holding the option for five years rather than exercising it immediately.

Following a similar procedure for the deferment option, the following parameters can be obtained:

S = 161.64 million; X = 148.01 million; r_f = 5.0%; σ = 20%; δ = 2.9825%.

Using Δt = 1 year as time step, u = 1.221; d = 0.819; p = 0.501. The binomial trees for the underlying asset value and expansion option are shown in Figure 3 and 4 respectively. As can be deduced from Figure 4, the value of growth option is RMB 76.42 million.

161.64	197.36	240.98	294.24	359.26	438.66
	132.38	161.64	197.36	240.98	294.23
		108.42	132.38	161.64	197.36
			88.79	108.42	132.38
				72.73	88.79
					59.56
t=0	t=1	t=2	t=3	t=4	t=5

Figure 3: Binomial Tree of Underlying Asset Value for Growth Option (in RMB million)

76.42	126.26	149.33	164.75	222.95	290.65
	23.38	39.19	63.86	99.84	146.22
		6.59	12.89	25.22	49.35
			0.00	0.00	0.00
				0.00	0.00
					0.00

Figure 4: Binomial Tree of Growth Option (in RMB million)

3.3.3 Evaluation of Multiple Options

In this example, the deferment option and growth option are both call options. Therefore, it is unlikely that option interaction is immaterial. If the degree of interaction is significant, the value of the two options cannot be added together in a straight forward manner. For example, the expansion option arising from the flexibility to implement Phase II would increase the value of the underlying for the deferment option.

To evaluate the combined value of both options, the fuzzy analytical hierarchy process is used. Three persons who have experience with highway development projects in China are interviewed. For each option, they are asked to provide their opinion on three aspects:

i. degree of influence of the specified option on the other option (**U$_1$**);
ii. likelihood of exercising the option (**U$_2$**);
iii. significance of the option to the corporate strategy of the project company (**U$_3$**).

Their opinion may be summarized in a matrix form as follows:

$$\text{Deferment:} \quad R_1 = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}_1 = \begin{bmatrix} 0.9 & 0.2 & 0.6 \\ 0.8 & 0.1 & 0.5 \\ 0.9 & 0.1 & 0.4 \end{bmatrix}_1$$

$$\text{Growth:} \quad R_2 = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}_2 = \begin{bmatrix} 0.8 & 0.9 & 0.8 \\ 0.6 & 0.8 & 0.6 \\ 0.8 & 1.0 & 0.7 \end{bmatrix}_2$$

Based on collective opinion, the weights attached to each aspect **U$_k$** to reflect their relative importance to the value of the combined option are found to be:

$$W = [\,0.5 \quad 0.2 \quad 0.3\,]$$

Following the procedure outlined in Section 2.1:

$$B_1 = W \circ (R_1)^T = [0.5 \quad 0.2 \quad 0.3] \circ \begin{bmatrix} 0.9 & 0.8 & 0.9 \\ 0.2 & 0.1 & 0.1 \\ 0.6 & 0.5 & 0.4 \end{bmatrix} = [0.67 \quad 0.57 \quad 0.59]$$

$$B_2 = W \circ (R_2)^T = [0.5 \quad 0.2 \quad 0.3] \circ \begin{bmatrix} 0.8 & 0.6 & 0.8 \\ 0.9 & 0.8 & 1.0 \\ 0.8 & 0.6 & 0.7 \end{bmatrix} = [0.82 \quad 0.64 \quad 0.81]$$

Next, based on the industrial experience and background of the interviewees, it is thought that the relative "degree of reliability" of the opinions given by the three interviewees is: **E$_1$** = 0.3, **E$_2$** = 0.4, **E$_3$** = 0.3. Thus, the fuzzy multiplier for each option can be evaluated:

$$f_1 = E \circ B_1^T = [0.3 \quad 0.4 \quad 0.3] \circ \begin{bmatrix} 0.67 \\ 0.57 \\ 0.59 \end{bmatrix} = 0.606$$

$$f_2 = E \circ B_2^T = [0.3 \quad 0.4 \quad 0.3] \circ \begin{bmatrix} 0.82 \\ 0.64 \\ 0.81 \end{bmatrix} = 0.745$$

Finally, the combined value of the two options are:

$$\begin{aligned} V_{total} &= f_1 V_{defer} + f_2 V_{growth} \\ &= (0.606 * 113.65) + (0.745 * 76.42) \\ &= 125.80 \text{ (RMB million)} \end{aligned}$$

Note that this is only 66% of the direct sum of the two option values (= 113.65 + 76.42 = 190.07). This result is consistent with Trigeorgis' [5] observation that when two options belong to the same type (in this case both are call options), their degree of interaction will be higher and the combined option value will be less than the direct sum of the option values.

4. Conclusion

Instead of evaluating the value of multiple real options implicitly, this paper applied the fuzzy analytical hierarchy process to combine option values explicitly. Although the method is more subjective, the strength lies with its simplicity. Furthermore, at one stage, the method seeks the direct input of experts, whose opinion is reflected in a more transparent manner. This attribute compares favorably against implicit evaluation, for which decision makers may view as a 'black box'.

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