Chapter XVII

The Application of Real Options to the R&D Outsourcing Decision

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Abstract

This chapter is a companion chapter to Chapter XVI, "Real Option Appraisal of R&D Outsourcing." We provide two real-world case studies of the application of real options to answer the question: "How do practicing planners and managers use and value flexibility in development projects?" The first case study we develop is based on the outsourcing decision-making process, more specifically, a two-stage vendor selection approach (applying real options theory) to adopting a supply chain management (SCM) system in a Shanghai-based transportation company — Chic Logistics. In the second case study, we use the example of the National Ignition Facility (NIF) to illustrate how decision-makers identify uncertainty and value flexibility in project analysis, and by deliberate decision, increase their options and thereby project value.

Real Option Methodology

The generally accepted methodology for valuing a financial call option is the Black-Scholes (1973) model. The difficulty with using this closed-form solution for valuing real options is it is difficult to explain, is applicable only in very specific situations, and limits the analyst's ability to model. On the other hand, the binomial lattice model, when used to price the movement in the asset value through time, is highly flexible. It is important to note the results are similar for the closed form Black-Scholes model and the binomial lattice approach. The more steps added to the binomial model, the better the approximation (Mun, 2002).

The binomial asset pricing model is based on a replicating portfolio that combines borrowing with ownership of the underlying asset to create a cash flow stream equivalent to that of the option. The model is created period by period with the asset value moving to one of two possible probabilistic outcomes each period. The asset has an initial value and within the first time period, either moves up to *Su* or down to *Sd*. In the second time period, the asset value can be any of the following: Su^2, *Sud*, Sd^2. The shorter the time interval, the smoother the distribution of outcomes (Amram & Kulatilaka, 1999).

The inputs for the binomial lattice model are equivalent to the inputs for the Black-Scholes model; namely, we need the present value of the underlying asset (S), the cost of exercising the option (X), the volatility of the cash flows (σ), the time until expiration (T), the risk free interest rate (r_f), and the dividend payout percentage (b). We use these inputs to calculate the up (u) and down (d) factors that are then used to find the risk neutral probabilities (p) that adjust asset values each time step (δt).

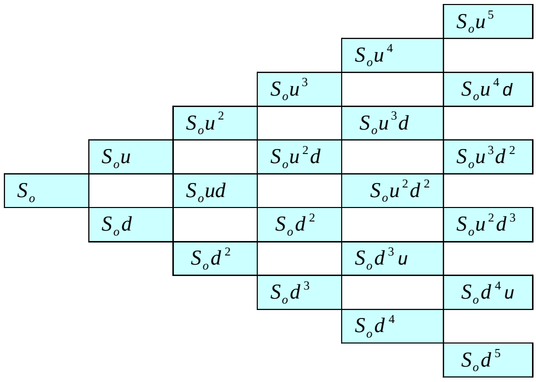
$$u = e^{\sigma\sqrt{\delta t}} \tag{1}$$

$$d = e^{-\sigma\sqrt{\delta t}} = \frac{1}{u} \tag{2}$$

$$p = \frac{e^{(r_f - b)(\delta t)} - d}{u - d} \tag{3}$$

where p reflects the probable outcomes that determine the risk free rate of return. Figure 1 shows the binomial lattice option model.

Figure 1. Binomial lattice option model



Case 1: Chic Logistics

Chic Logistics Incorporated (CLI) is a $40 million Shanghai-based transportation company with funding from American Venture Capitals. Johnson Shen, CEO and the founder of the company, states "China's economy is growing in such a rapid pace that traditional transportation and warehousing systems have been unable to meet the increasingly sophisticated demands of the market. A modern approach to logistics management provides our customers with higher efficiency, more diversification of services, and above all, better technology." In 2004, CLI determined to make the transformation by adopting a supply chain management information system (SCMIS). Due to limited in-house IT capabilities, CLI decided to outsource the SCMIS project based on the rationale that purchasing IT components/services from external vendors would allow them to enjoy the benefits of specialization and lower costs. CLI faced two dilemmas of IT outsourcing. First, there are too many SCMIS vendors to choose from in China. Initially, they found 13 qualified SCMIS vendors in China and later they reduced the selection of vendors to 2 finalists (SSA Global and EXE Technologies) using a Delphi Method (a subjective selection approach).

However, CLI still needs to figure out an analytical screening approach in choosing the final vendor. Second, by its very nature, IT projects such as SCMIS are intangible products and, as such, it is difficult to identify vendor capabilities and assess vendor performance objectively. CLI decided to employ a two-stage outsourcing approach. In the first stage, namely, the prototype stage, CLI will invest $100,000 in both SSA Global and EXE Technologies. In the prototype stage, CLI engages each company for a pilot project and observes the outcome. Based on the outcome of the pilot projects, CLI decides whether to continue the project with one of these two companies to the second stage or to terminate the project.

Real option analysis (ROA) was chosen by CLI as the methodology for the vendor selection process. Using ROA, CLI was able to decide not only which vendor to select but also determine what is the optimal level of investment at each stage.

CLI Results

Presuming an initial firm value of $40 million, volatility of 15%, and a time period between steps of 0.20 years, the lattice for CLI if the firm were not to outsource to either firm appears below. In CLI's case, $u = e^{\sigma\sqrt{d_t}} = e^{0.15\sqrt{(0.20)}} = 1.055$ and $d = \frac{1}{u} = \frac{1}{1.055} = 0.95$. The volatility calculation is estimated by CLI based on historic volatility of previous IT R&D projects. The binomial tree indicates the R&D project value will vary from $52.31 million to $30.59 million at the end of five periods (Figure 2).

The projected future cash flows for CLI without an SCMIS range from a high of $52.3 million to a low of $30.58 million. CLI can alter these growth projections by choosing to outsource to one of two firms: SSA or EXE. Applying the same valuation approach as for CLI without outsourcing, CLI projects that if it outsources to SSA, the range of possible net present value cash flows due to outsourcing will vary between $5.3 million and $7.7 million with a probabilistic expected value of $6.54 million (Table 1). By running a Monte Carlo simulation,

Figure 2. CLI's underlying asset lattice

					52311.05
				49577.74	
			46987.25		46987.25
		44532.12		44532.12	
	42205.27		42205.27		42205.27
40000.00		40000.00		40000.00	
	37909.96		37909.96		37909.96
		35929.12		35929.12	
			34051.79		34051.79
				32272.55	
					30586.27

Table 1. Forecasted values before option valuation

	Forecasted Cash Flows ($1,000,000)			
	Minimum	**Maximum**	**Present Expected Value ($1,000,000)**	**Volitility**
CLI	30.6	52.3	40.0	15%
SSA	4.7	9.1	6.5	12%
EXE	2.3	10.3	4.8	34%

Figure 3. SSA's underlying asset lattice

					9153.27
				8559.40	
			8004.05		8004.05
		7484.73		7484.73	
	6999.11		6999.11		6999.11
6545.00		6545.00		6545.00	
	6120.35		6120.35		6120.35
		5723.25		5723.25	
			5351.92		5351.92
				5004.68	
					4679.97

Figure 4. EXE's underlying asset lattice

					10351.98
				8891.76	
			7637.52		7637.52
		6560.19		6560.19	
	5634.83		5634.83		5634.83
4840.00		4840.00		4840.00	
	4157.28		4157.28		4157.28
		3570.87		3570.87	
			3067.17		3067.17
				2634.53	
					2262.91

CLI derives a volatility estimate of 12% for SSA. On the other hand, the present value of the cash flows from partnering with EXE range from $3 million to $7 million with an expected value of $4.84 million and a volatility estimate of 34% when derived from the simulation. SSA's expected future cash flows range from $9.1 million to $4.68 million, while EXE has a larger upside potential with maximum expected cash flows of $10.3 million; however, on the downside, the lower expected cash flows for EXE are $2.26 million. The binomial lattices for SSA and for EXE appear in Figures 3 and 4.

To calculate the value of the option, ROA requires the future value of the projected cash flows be discounted back to the present. To calculate the value at each node, S, the present value is calculated as follows:

$$S = [Sup + Sd(1 - p)]e^{-rt} \quad (4)$$

Figure 5. Option valuation lattice CLI and SSA

					61364.32
				58085.32	
			54981.87		54891.30
		52044.54		51959.24	
	49264.42		49184.07		49104.38
46633.08		46557.39		46482.31	
	44071.22		44000.48		43930.31
		41651.38		41585.25	
			39365.56		39303.71
				37206.22	
					35166.24

Figure 6. Option valuation lattice CLI and EXE

					62563.03
				58761.22	
			55212.89		54524.77
		51899.12		51281.83	
	48802.59		48248.81		47740.10
45907.38		45410.55		44954.12	
	42753.14		42343.59		41967.24
		39896.24		39558.49	
			37297.65		37018.96
				34924.53	
					32749.18

Table 2. Values of SCMIS development strategies with options

	Forecasted Cash Flows ($1,000,000)		
	Minimum	Maximum	Present Expected Value
CLI	30.6	52.3	40.0
CLI & SSA	35.2	61.4	46.6
CLI & EXE	32.7	62.6	45.9

Beginning at the far right side of the lattice, the nodes are calculated period by period and rolled back to arrive at the present value of the investment project. The expected future cash flows of the SCMIS strategy when partnering with SSA is $46, 633.08 whereas the value of CLI partnering with EXE is $45,907.38. Table 2 presents a comparison of CLI's three options: to choose not to partner, to partner with SSA, or to partner with EXE.

Clearly, CLI should outsource. Both projects create value for the firm which far exceeds the $100,000 in prototype development costs. Whereas CLI has a present value of $40 million, with either an outsourcing venture with SSA or CLI, additional firm value is created. As the lattices show, despite the higher upside potential for a CLI/EXE outsourcing project ($62.563 million vs. $61.364 million), CLI realizes the greater value by outsourcing to SSA. Whereas a project to outsource to EXE yields an expected $45.907 million in present value (or, an additional $5.907 million incremental value), a venture with SSA leads to an expected value increase of $6.633 million due to options. CLI should choose to outsource to SSA.

For this particular project, we have consistency: both NPV and ROA lead to the conclusion that CLI should outsource to SSA. This is not surprising. For the same initial investment, SSA yields $6.54 million in present value whereas EXE only yields $4.84 million, a difference of 35%. Real option analysis adds real value to decision analysis when the outcome is not so clear-cut. With a vendor selection problem, it is more common to find a case where the expected cash flows are more similar. When this occurs, and the volatility of the cash flows for the two vendors is different, we typically see real option and NPV decisions that conflict. Although NPV and real option analysis led to the same decision in this case, for projects with growth opportunities, this frequently is not the case. For projects with growth options, the decision criterion should be to accept the project with the greatest real option value.

Not all projects are quantifiable like Chic Logistics. In some cases, managers cannot determine a point estimate of a future value. However, in these cases, real option analysis can be used to focus and improve managers' thinking. The National Ignition Facility case demonstrates this use of real option analysis.

Case 2: National Ignition Facility

The National Ignition Facility (NIF) is a nuclear explosion laboratory developed by the U.S. Department of Energy to create new means of stockpile testing and research (Lawrence Livermore National Laboratory, 2005). The facility exists largely due to the Comprehensive Nuclear Test-Ban Treaty signed by the United States in 2001, which banned the traditional ways of testing nuclear weapons.

NIF needed to develop slabs of laser glass blanks to be used in the testing of nuclear weapons and research. Laser glass procurement requires the production of high quality glass slabs called "blanks," the finishing of the blanks, and the coating of the blanks. Blanks for smaller lasers could be produced in batch processes. But the NIF project scaled up the laser size to about ten times that of the largest existing laser. No glass production technologies capable of producing the volume of glass blanks needed by NIF existed or were under development at the start of the project.

The ability of glass firms to develop feasible new glass production technologies and the quality of the glass produced if the production technologies were feasible were uncertain, as were costs and development schedules. NIF chose to hire two firms to begin initial research into the development of a technology to produce the blanks. At stages throughout the process, NIF had the ability to choose to (a) continue funding both companies and their technology development; (b) fund only one company going forward; or (c) discontinue funding both companies and explore alternative sources for the blank development. The choice at each step was based on the success of the outsourcing firms in meeting expectations and the cost of continuing to fund the research and development.

Through real option analysis, NIF was able to assess the cost effectiveness of its options at each stage. This analysis assisted managers in project management decision-making by providing a reliable decision tool.

Research and Development for Laser Glass Production Technology

NIF spent more than $350 million to produce over 3,000 pieces of laser glass. Laser glass begins as slabs of very high quality glass called “blanks.” The large volume of blanks and project schedule and budget required a production rate 30 times larger and five times cheaper than was used on prototype lasers. This required the development of a new glass production technology. Glass vendors could not justify funding the development. Therefore, NIF invested in glass production technology R&D (Campbell, 2001). The R&D of a high-volume continuous-melting glass production process included two critical uncertainties: whether the technology could make the glass; and whether the quality of the glass would be acceptable. The threat posed by these uncertainties was that, if R&D efforts failed in either way, the project could be delayed too long to meet its deadline and would incur very high unbudgeted costs. Although NIF had relationships with experienced laser glass vendors, none could guarantee successful development within the required time a priori. NIF needed a higher likelihood of success than any one vendor could provide. Therefore, alternatives to a one-vendor strategy were considered during laser glass procurement planning.

In the laser glass case, the managed asset is the NIF project and the underlying uncertainty is the likelihood of a vendor successfully developing a feasible glass production technology with the required quality. NIF managers acquired several options to manage laser glass production technology R&D, including flexibility in funding, schedules, sharing of expertise and human resources, and other technologies. However, the most critical option was incorporated into the R&D procurement strategy (Ford & Ceylan, 2002). A base strategy would invest in a single production development effort, hoping for a successful development. An alternative strategy would simultaneously make initial investments in two phased independent R&D efforts by two glass producers. The latter strategy would provide two managerial options as well as increasing the likelihood that at least one effort would be successful. First, phased R&D would provide options for NIF to delay its decisions about the amount of support (if any) to provide each vendor until some technology feasibility uncertainty was resolved. Second, investing in two vendors would provide the following option based on the primary underlying uncertainty, what R&D effort or efforts would succeed. If only one effort succeeded, managers could abandon the failed effort, use the successful one, and avoid the consequences of having no successful glass production system. If both vendors succeeded, NIF could choose the better, or both.

The sequential investments in each vendor can be structured as a staged development process of options to extend support if adequate progress is demonstrated; or an option to abandon the vendor if adequate progress cannot be demonstrated. This flexibility initially would cost NIF approximately $12 million for either vendor. The flexibility provided by investing in multiple vendors can be structured as an option to choose the successful vendor (if only one succeeds), choose the more successful vendor (if both succeed), or retain both vendors (if both succeed). The cost of this flexibility is the funds required to invest in a second vendor (approximately $12 million). Given the uncertainties, potential costs, and benefits, the NIF managers had to assess whether the one-vendor or two-vendor strategy would best serve NIF and how to implement the chosen strategy.

Despite a plethora of factors that influenced strategy attractiveness, the option analysis centered on the comparison of scenario sets (Alessandri, Ford, Lander, Leggio & Taylor, 2004). If a single vendor was selected, the development might succeed. But if the single vendor failed, the costs to the project in time, money, and political consequences would prevent the project from meeting its targets. Previous embarrassing and costly NIF failures to meet targets made this scenario tantamount to the death of the project to the NIF managers. In contrast, if two vendors were selected, none, one, or two could succeed. The likelihood of two failures was considered very low because of the many other project management tools and options available to managers (Moses, 2001). One or two successes would protect NIF from project failure. The avoided costs of project failure if investments were made in two vendors were (informally) estimated to greatly exceed the additional cost of investing in a second vendor (about 0.5% of the project budget), even if the avoided costs were discounted at any reasonable rate to account for the time value of money. Therefore, the option was considered more valuable than its cost. Based on this reasoning, NIF selected a two-vendor strategy and contracted with two vendors to initiate parallel R&D efforts. The uncertainty about technology viability was resolved when both vendors successfully produced pilot runs of glass using continuous-melting processes. Due largely to the remaining uncertainties, NIF chose to continue investment in both vendors. Quality uncertainty was resolved when both vendors also demonstrated the ability to generate the required glass quality. NIF chose again to continue with both vendors to retain manufacturing and pricing flexibility. Each time NIF managers chose to support both vendors, NIF purchased quality, production, or pricing flexibility that they could use to manage other project uncertainties (e.g., funding profile changes). The costs avoided with these options were significant, albeit less than those saved in case of a development failure.

Conclusion

The Chic Logistics case illustrates how practicing mangers can use a formal (i.e., mathematical) model to estimate asset values with flexible strategies. These values were then used to improve strategic decision-making about outsourcing. The NIF laser glass production technology R&D case illustrates how practicing managers can use options to increase project value, even without formal valuation modeling. NIF managers included the monetary, schedule, and political consequences of strategy choices into their assessment of option values and thereby integrated the richness of the project into strategic decision-making.

A major challenge for corporate and project senior leaders is to more fully understand how to identify, evaluate, and manage the risks and uncertainties facing their organizations. Yet the complexity of many industries makes this task difficult. A thorough understanding of the risk factors that contribute to the variability in a firm's earnings and project values can determine the survivability of the firm, and will enhance the abilities of executives to anticipate competitive, environmental, regulatory, and legislative changes and their impacts. Executives are increasingly being called upon to meet financial expectations, manage risk to stabilizing earnings, and increase the firm's potential survivability. In this era, managing the firm's risk, and the firm, under conditions of uncertainty, becomes critical. Real options are a means to manage risk whether the analysis is in the traditional quantitative analysis demonstrated in the CLI case or in the strategic thinking used to make the NIF decision.

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