CHAPTER 13

REAL OPTIONS AND OTHER TOPICS IN CAPITAL BUDGETING

Keeping Your Options Open

The last two chapters described the basic procedures used in capital budgeting, including cash flow estimation and adjusting for project risk. Those procedures assume that the expected cash flows are locked in once the project has been accepted. However, the resulting NPV may be misleading if managers are able to modify operations in reaction to changing circumstances, thereby altering the initially forecasted cash flow stream. For example, if demand turns out to be stronger than anticipated, it might be possible to expand the plant, increase output, and thus increase the NPV.

In this chapter, we describe *real option analysis*, which incorporates the possibility of mid-course corrections into the traditional NPV analysis. The possible corrections are called *embedded real options*, or choices. For example, the initial analysis might indicate that a project has a negative NPV, but if the operation could be expanded if demand turns out to be stronger than was anticipated, this might change the expected NPV from negative to positive. Other types of real options include changing a plant's output (say, from sedans to SUVs if the auto market changes), abandoning a project that is generating lower than anticipated cash flows, or waiting to see how the market is developing before making the final go/no-go decision. As we will demonstrate, all of these possibilities can lead to increases in the expected NPV and thus to a change in the accept/reject decision.

A recent article in the *Journal of Applied Corporate Finance* reported that companies like Intel, Texaco, and Genentech use real option analysis extensively in capital budgeting. While the analysis can be quite complex, the basic principles are straightforward and can be described in simple terms. After reading this chapter, you should see why real option analysis is important in capital budgeting.

Source: Alex Triantis and Adam Borison, "Real Options: State of the Practice," *Journal of Applied Corporate Finance*, Vol. 14, no. 2 (Summer 2001), pp. 8–24.

Putting Things In Perspective

Chapters 11 and 12 covered the basic principles of capital budgeting. Now we examine three important extensions. First, we discuss real options and present some examples to demonstrate their importance. Next, we discuss mutually exclusive projects that have unequal lives. As we shall see, if such projects can be repeated, the analysis must be extended out into the future to make a valid comparison and thus make the right choice between the alternatives. Finally, we discuss the relationship between the size of the capital budget and the WACC. The WACC tends to increase as the firm raises larger and larger amounts of capital, creating a feedback relationship between the size of the capital budget and the WACC.

13.1 INTRODUCTION TO REAL OPTIONS[1]

Traditional discounted cash flow (DCF) analysis—where cash flows are estimated and then discounted to obtain the expected NPV—has been the cornerstone for capital budgeting since the 1950s. However, in recent years it has been demonstrated that DCF techniques do not always lead to proper capital budgeting decisions.[2]

DCF techniques were originally developed to value securities such as stocks and bonds. Those securities are passive investments—once they have been purchased, most investors have no influence over the cash flows they produce.[3] However, real assets are not passive investments—managers can often take actions to alter the cash flow stream. Such opportunities are called **real options**—"real" to distinguish them from financial options like an option to buy shares of GE stock, and options because they provide the right but not the obligation to take some future action that can increase cash flows. Real options are valuable, and as this value is not captured by conventional NPV analysis, it must be considered separately.

Real Option
The right but not the obligation to take some action in the future.

There are several types of real options, including (1) *abandonment*, where the project can be shut down if its cash flows are low; (2) *timing*, where a project can

[1] Real option analysis is relatively technical, and the topic is covered in depth in advanced corporate finance courses. However, since many students do not take additional finance courses, and since this is an important topic, we provide this introduction. However, Sections 13.1 through 13.5 may be omitted without loss of continuity if there is insufficient time to cover it.

[2] For an early but excellent discussion of the problems inherent in discounted cash flow valuation techniques as applied to capital budgeting, see Avinash K. Dixit and Robert S. Pindyck, "The Options Approach to Capital Investment," *Harvard Business Review*, May–June 1995, pp. 105–115. For more information on the option value inherent in investment timing decisions, see Stephen A. Ross, "Uses, Abuses, and Alternatives to the Net-Present-Value Rule," *Financial Management*, Autumn 1995, pp. 96–101. Also, the Summer 2001 issue of the *Journal of Applied Corporate Finance* contains several interesting articles on the use of option concepts in capital budgeting.

[3] Large investors such as Warren Buffett and some hedge fund operators can buy stock in companies and then influence the firms' operations and cash flows. However, the average stockholder does not have such influence.

be delayed until more information about demand and/or costs can be obtained; (3) *expansion*, where the project can be expanded if demand turns out to be stronger than expected; (4) *output flexibility*, where the output can be changed if market conditions change; and (5) *input flexibility*, where the inputs used in the production process (say, coal versus oil for generating electricity) can be changed if input prices and/or availability change.

SELF TEST

Why might DCF techniques not always lead to proper capital budgeting decisions?

What is a real option?

Why might recognizing a real option raise but not lower a project's NPV as found in a traditional analysis?

What are the five types of real options? Briefly explain each one.

13.2 ABANDONMENT/SHUTDOWN OPTIONS

In capital budgeting we generally assume that a project will be operated for its full physical life. However, this is not always the best course of action. If the firm has the **option to abandon** a project during its operating life, this can lower its risk and increase its expected profitability.

Abandonment Option
The option of abandoning a project if operating cash flows turn out to be lower than expected. This option can both raise expected profitability and lower project risk.

Recall from Chapter 12 that due to contractual obligations to component suppliers, BQC's computer control project could not be terminated before the end of its four-year life. Under that constraint, we evaluated the best-case, base-case, and worst-case scenarios. The earlier analysis is reproduced in the decision tree given in Situation 1 of Table 13-1, "Cannot Abandon." In Column B we see the probabilities for each scenario. In Column C, which is Time 0, we see that the firm must invest $26 million. Columns D through G show the annual cash flows under each scenario, and in Column H we show the NPV under each scenario when the cash flows are discounted at a 12 percent WACC. The sum of the products obtained by multiplying each probability times each branch NPV is the expected NPV, which is $13.531 million. The standard deviation and the coefficient of variation are also calculated to provide an idea of the project's risk. This project has a positive expected NPV based on the 12 percent WACC, but management might choose to reject it because if things turn out badly the company would be seriously damaged (as illustrated in Row 20 of Table 13-1).

Now suppose the constraint against closing the operation could be relaxed, and the company could make a second decision, at $t = 1$, to abandon (or shut down) the project if things turn out badly. To see what would happen then, we add another branch to the tree, as shown in Situation 2 of Table 13-1. Here we assume that the company *can abandon* the project at the end of Year 1, when information about the actual production costs and demand conditions become available. If things were going well, the project would be continued. However, if things were going badly, BQC would sell the related assets at their $18.244 million book value and realize this cash flow at the end of Year 2. (There would be no tax consequences, as a sale at book value produces neither a gain nor a loss.) Thus, the Year 2 cash flow would be a positive $18.244 million rather than the loss of $8.943 million if the operation were continued. Of course, if the project were abandoned, the cash flows in Years 3 and 4 would become zero. With these changes, we recalculate the NPV for the bottom (or "Can Abandon") branch. It is still negative, but

TABLE 13-1 *Decision Trees without and with the Abandonment Option (Dollars in Thousands)*

	A	B	C	D	E	F	G	H	I
15	Situation 1: Cannot Abandon				WACC =	12%			
16			End-of-Period Cash Flows:					NPV @	
17		Prob:	0	1	2	3	4	12%	
18	Best Case	25%	−26,000	33,810	34,257	33,841	50,224	$87,503	
19	Base Case	50%	−26,000	6,702	7,149	6,733	23,116	5,166	
20	Worst Case	25%	−26,000	−9,390	−8,943	−9,359	7,024	−43,711	
21							Expected NPV	$13,531	
22						Standard Deviation (SD)		$47,139	
23						Coefficient of Variation (CV)		3.48	
24									
25	Situation 2: Can Abandon				WACC =	12%			
26			End-of-Period Cash Flows:					NPV @	
27		Prob.	0	1	2	3	4	12%	
28	Best Case	25%	−26,000	33,810	34,257	33,841	50,224	$87,503	
29	Base Case	50%	−26,000	6,702	7,149	6,733	23,116	5,166	
30	Worst #1	0%	−26,000	−9,390	−8,943	−9,359	7,024	−43,711	Disregard
31	Worst #2	25%	−26,000	−9,390	18,244	0	0	−19,840	Choose
32							Expected NPV	$19,499	
33						Standard Deviation (SD)		$40,567	
34						Coefficient of Variation (CV)		2.08	
35									
36			Abandonment Option Value						
37			Expected NPV w/ Abandonment					$19,499	
38			Expected NPV w/o Abandonment					13,531	
39			Difference = Abandonment Option Value					$ 5,968	

considerably less negative than in the worst-case scenario before considering abandonment.[4]

The option to abandon raises the expected NPV from $13.531 million to $19.499 million, and it also lowers the standard deviation. Those changes combine to lower the coefficient of variation. The coefficient of variation is 2.08, which is close to the company's average of 2.0, which indicates that the project is of average risk once abandonment is factored in. Therefore, the 12 percent WACC is appropriate. Also, note that the difference between the expected NPVs with and without abandonment represents the **value of the option** to abandon. As shown in the lower part of Table 13-1, the option is worth $5.968 million.

Option Value
The difference between the expected NPVs with and without the relevant option. It is the value that is not accounted for in a traditional NPV analysis. A positive option value expands the firm's opportunities.

In this case, the ability to abandon makes the NPV look better, but it does not reverse the accept/reject decision. However, it often turns out that if we fail to consider abandonment, the bad case is so bad that the expected NPV is negative, but when abandonment is considered, the expected NPV becomes positive. Clearly, abandonment must be considered to obtain valid assessments for different projects, and the opportunity to abandon is an important way to limit downside losses.

Note too that it might be necessary for the firm to arrange things so that it has the possibility of abandonment when it is making the initial decision. This

[4] In Situation 2, where the company has the option to abandon if the worst-case scenario occurs, it would abandon the project as that action would minimize its losses. Thus, we show a zero probability of continuing to operate under the worst-case scenario.

might require contractual arrangements with suppliers, customers, and its union, and there might be some costs to obtaining the advance permissions. Any such costs could be compared with the value of the option as we calculated it, and this could enter into the initial decision.

SELF TEST

Would you expect an abandonment option to increase or decrease a project's NPV and risk as measured by the coefficient of variation? Why?

How could the value of the abandonment option be estimated?

13.3 INVESTMENT TIMING OPTIONS

A conventional NPV analysis assumes that projects will either be accepted or rejected, which implies that they will be undertaken now or never. However, in practice companies sometimes have a third choice—delay the decision until later, when more information becomes available. Such **investment timing options** can affect a project's estimated profitability and risk.

Investment Timing Option
An option as to when to begin a project. Often, if a firm can delay a decision, it can increase a project's expected NPV.

To illustrate timing options, assume that Williams Inc. is considering a project that requires an initial investment of $5 million at the beginning of 2006 (or $t = 0$). The project will generate positive net cash flows at the end of each of the next four years ($t = 1, 2, 3$, and 4). However, the size of each annual cash flow will depend on what happens to future market conditions. Table 13-2 shows two decision trees that illustrate the problem. As shown in the top section, there is a 50 percent probability that market conditions will be strong, in which case the project will generate cash flows of $2.5 million at the end of each of the next four years. There is also a 50 percent probability that demand for the product will be weak, in which case the annual cash flows will be only $1.2 million.

Note that each branch of the decision tree is equivalent to a time line. Thus, the top line, which describes the payoffs under good conditions, shows a cost of $5.0 million in 2006 and cash inflows of $2.5 million for 2007 through 2010. Williams considers the project to have average risk, hence it will be evaluated using a 10 percent WACC. The NPV, if the market is strong, will turn out to be $2.92 million. On the other hand, if product demand is weak, the NPV will turn out to be −$1.20 million, so it will be a money loser.

The expected value is found as a weighted average of the NPVs of the two possible outcomes, with each outcome's weight being its 50 percent probability. The expected NPV, if the project is undertaken today, is $0.864 million. The project has a positive NPV, so it appears that the company should proceed with it, even though there is some risk, and there is a 50–50 chance that it will actually turn out to be a loser.

However, suppose Williams can delay the project until next year, when more information will be available about market conditions, before making the decision. If conditions are good, the firm will proceed, but if they are bad, it will not make the investment, hence the NPV will be zero. The probability of each outcome is 50 percent, and the expected NPV is $1.462 million, almost twice that as if we go ahead right now and possibly have the low cash flows under the bad conditions. Note, though, that if the firm waits, the expected NPV will come a year later. Therefore, we discount the expected NPV under the delay option at the WACC to get an adjusted NPV of $1.329 million. Since this exceeds the NPV under the proceed immediately decision, Williams should delay the project for a year.

When making go-versus-wait decisions, financial managers need to consider several other factors. First, if a firm decides to wait, it may lose strategic advantages

TABLE 13-2 *Illustration of a Timing Option (Dollars in Millions)*

Proceed Immediately: Invest Now

		END-OF-PERIOD CASH FLOWS:					
Conditions	**Probability**	**2006**	**2007**	**2008**	**2009**	**2010**	**NPV @ 10%**
Good	50%	(5.0)	2.5	2.5	2.5	2.5	$2.92
Bad	50%	(5.0)	1.2	1.2	1.2	1.2	(1.20)

Expected NPV	$0.864
Standard deviation	$2.060
Coefficient of variation	2.38

Delay Decision: Invest Only If Conditions Are Good

		END-OF-PERIOD CASH FLOWS:						
Conditions	**Probability**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**NPV @ 10%**
Good	50%	Delay	(5.0)	2.5	2.5	2.5	2.5	$2.92
Bad but irrelevant	50%	Delay	0.0	0.0	0.0	0.0	0.0	0.00

Expected NPV	$1.462
Standard deviation	$1.462
Coefficient of variation	1.00
Discount expected NPV 1 year to make it comparable to "Invest Now" NPV	$1.329
Expected NPV with the timing option	$1.329
Expected NPV without the timing option	0.864
Difference = Timing option value	$0.465

associated with being the first supplier in a new line of business, and this could reduce the cash flows. On the other hand, as we saw in the preceding example, waiting may enable the company to avoid a costly mistake. In general, the more uncertainty there is about future market conditions, the more attractive it becomes to wait, but this risk reduction may be offset by the loss of the "first mover advantage." Again, any such first mover advantage can be compared with the value of the option.

SELF TEST

Briefly describe what investment timing options are and why they are valuable.

Explain why the following statement is true: "In general, the more uncertainty there is about future market conditions, the more attractive it is to delay the decision."

Growth Option
If an investment creates the opportunity to make other potentially profitable investments that would not otherwise be possible, then the investment is said to contain a growth option.

13.4 GROWTH OPTIONS

We can illustrate **growth options** with a distribution center in mainland China being considered by the Crum Corporation. An investment of $3 million would be required at t = 0. Under good conditions the project would generate cash flows of $1.5 million during each of the next 3 years (t = 1, 2, and 3), but under

TABLE 13-3 *Analysis of a Growth Option (Dollars in Millions)*

Project without the Growth Option

		END-OF-PERIOD CASH FLOWS:				
		0	**1**	**2**	**3**	**NPV @ 12%**
Good	50%	(3.00)	1.50	1.50	1.50	$0.603
Bad	50%	(3.00)	0.75	0.75	0.75	(1.199)
					Expected NPV	($0.298)

Project with the Growth Option

			END-OF-PERIOD CASH FLOWS:				
			0	**1**	**2**	**3**	**NPV @ 12%**
Good	Distribution Center	50%	(3.00)	1.50	1.50	1.50	
	New Investment				(10.00)	20.00	
			(3.00)	1.50	(8.50)	21.50	$6.866
Bad	Distribution Center	50%	(3.00)	0.75	0.75	0.75	(1.199)
						Total expected NPV	$2.834
						Expected NPV with growth	$2.834
						Expected NPV without growth	(0.298)
						Difference = Growth option value	$3.132

bad conditions its cash flows would be only $0.75 million. There is a 50 percent probability of each outcome. Crum uses a WACC of 12 percent for international investments.

As shown in the top section of Table 13-3, the distribution center's NPV is −$0.298 million, so under a traditional analysis it would be rejected. However, Crum believes that if it invests in the distribution center and conditions are good, it will gain experience that will give it the opportunity to make another investment in China. The new venture would cost $10 million at t = 2, and it could be sold for cash one year after it is completed, at t = 3, for $20 million.

As we show in the top section of the table, taken alone the distribution center does not appear to be a good investment. However, when the growth opportunity is considered, the project has a positive NPV and thus should be accepted.

SELF TEST

If a firm fails to consider growth options, would this cause it to underestimate or overestimate projects' NPVs? Explain.

13.5 FLEXIBILITY OPTIONS

Flexibility Option
An investment that permits operations to be altered depending on how conditions change during a project's life.

Many projects offer **flexibility options** that permit the firm to alter operations depending on how conditions change during the project's life. Typically, inputs, outputs, or both can be changed. BMW's Spartanburg, South Carolina, auto assembly plant provides a good example of a flexibility option. BMW needed the plant to produce sports coupes. If it built the plant configured optimally to produce these vehicles, the construction cost would be minimized. However, the company thought that later on it might want to switch production to some other type of vehicle, and that would be difficult if the plant were designed just for coupes. Therefore, BMW decided to spend additional funds to construct a more flexible plant, one that could produce several different models should demand patterns shift. Sure enough, things did change. The demand for coupes dropped, while the demand for sports utility vehicles soared. But BMW was ready, and the Spartanburg plant is now spewing out hot-selling SUVs. The plant's cash flows are much higher than they would have been without the flexibility option that BMW "bought" by building a more flexible plant.

Electric utilities provide a good example of building input flexibility into capital budgeting projects. Utilities can build plants that generate electricity by burning coal, oil, or natural gas. The prices of those fuels change over time depending on developments such as actions in Iraq or Iran, changing environmental policies, and weather conditions. Some years ago, virtually all power plants were designed to burn one type of fuel because this resulted in the lowest construction cost. However, as fuel cost volatility increased, power companies began to build higher-cost but more flexible plants, especially ones that could switch from oil to gas and back again, depending on relative fuel prices.

Flexibility options tend to reduce the risk of a bad outcome, and this increases the expected NPV and reduces risk. Of course, flexibility options do have costs, but those costs can be compared with the benefits of the options as we have demonstrated in the examples presented earlier.

SELF TEST

What are "input flexibility options" and "output flexibility options?"

How do flexibility options affect projects' NPVs and risk?

13.6 COMPARING MUTUALLY EXCLUSIVE PROJECTS WITH UNEQUAL LIVES

If a company is choosing between two mutually exclusive projects with significantly different lives, an adjustment may be necessary. For example, suppose BQC is planning to modernize a distribution center, and it is choosing between a conveyor system (Project C) and a fleet of forklift trucks (Project F). Figure 13-1, Part I, shows the traditional analysis that might be used to analyze the two projects. We see that Project C, when discounted at a 12 percent WACC, has the higher NPV and thus it appears to be the better project.

Replacement Chain (Common Life) Approach
A method of comparing projects with unequal lives that assumes that each project can be repeated as many times as necessary to reach a common life span; the NPVs over this life span are then compared, and the project with the higher common-life NPV is chosen.

However, the traditional analysis is incomplete, and the decision to choose Project C is actually incorrect. If we choose Project F, we will have an opportunity (a real option) to make a similar investment in three years, and if cost and revenue conditions remain at the Part I levels, this second investment will also be profitable. If we choose Project C, we will not have the option to make this second investment. Therefore, to make a proper comparison between C and F we must make an adjustment. There are two methods for making the adjustment and we discuss them in the remainder of this section.

Replacement Chains

First, we could apply the **replacement chain (common life) approach** as shown in Part II of Figure 13-1. This involves finding the NPV of Project F over six years, which is the life of Project C, and then comparing this extended NPV with

FIGURE 13-1 *Analysis of Mutually Exclusive Projects with Unequal Lives*

I. Traditional Analysis **WACC = 12%**

Project C

0	1	2	3	4	5	6
($40,000)	$8,000	$14,000	$13,000	$12,000	$11,000	$10,000

NPV_C = $6,491 IRR_C = 17.47%

Project F

0	1	2	3
($20,000)	$7,000	$13,000	$12,000

NPV_F = $5,155 IRR_F = 25.20%

II. Replacement Chain Method for Adjusting for Unequal Lives
WACC = 12%

Project C: No change in the analysis

0	1	2	3	4	5	6
($40,000)	$8,000	$14,000	$13,000	$12,000	$11,000	$10,000

NPV_C = $6,491 IRR_C = 17.47%

Project F: Replacement chain modification

0	1	2	3	4	5	6
($20,000)	$7,000	$13,000	$12,000			
			($20,000)	$7,000	$13,000	$12,000
($20,000)	$7,000	$13,000	($8,000)	$7,000	$13,000	$12,000

NPV_F = $8,824 IRR_F = 25.20%

III. Equivalent Annual Annuity (EAA) Method for Adjusting for Unequal Lives

For Project C, insert these values into a calculator: N = 6, I/YR = 12, PV = –6491, and FV = 0. Press PMT to find the constant annuity payment whose PV is $6,491. This payment is

EAA_C = $1,578.78

Then do the same thing with Project F, using N = 3, I/YR = 12, PV = –5155, and FV = 0. Solve for PMT:

EAA_F = $2,146.28

the NPV of Project C over the same six years. We see that on a common life basis F turns out to be the better project.[5]

Equivalent Annual Annuities (EAA)

Electrical engineers designing power plants and distribution lines were the first to encounter the unequal life problem. They could use transformers and other

[5] In this case, we only need to extend F's life out for one replacement. However, if C had a life of seven years and F had a life of three years it would have been necessary to go out to Year 21, using three replacements for C and seven for F, in order to reach a common life span.

equipment that had relatively low initial costs but short lives, or they could use equipment that had higher initial costs but longer lives. The services would be required on into the indefinite future, so this was the issue: Which choice would result in the higher NPV in the long run? The engineers converted the annual cash flows under the alternative investments into a constant cash flow stream whose NPV was equal to, or equivalent to, the NPV of the initial stream. This was called the **equivalent annual annuity (EAA) method.** To apply the EAA method to Projects C and F, for each project we simply find the constant payment that has the same NPV as the project's traditional NPV. The project with the higher EAA is the better project, and as we can see from Figure 13-1, Project F is the better one.

Equivalent Annual Annuity (EAA) Method
A method that calculates the annual payments a project would provide if it were an annuity. When comparing projects with unequal lives, the one with the higher equivalent annual annuity (EAA) should be chosen.

Conclusions about Unequal Lives

The replacement chain and EAA methods always result in the same decision, so it doesn't matter which one is used. The EAA is a bit easier to implement, but the replacement chain method is often easier to explain to senior managers. Also, it is easier to make modifications to the replacement chain data to deal with anticipated productivity improvements and asset price changes. For these reasons, we generally use the replacement chain method when we work with nonengineers, but when engineers are involved, we show both results.

Another question often arises: Do we have to worry about unequal life analysis for all projects that have unequal lives? As a general rule, the unequal life issue (1) does not arise for independent projects but (2) it can be an issue when we compare mutually exclusive projects with significantly different lives, but *only if there is a high probability that the projects will actually be repeated at the end of their initial lives.* For independent projects and for mutually exclusive but not repeatable projects, there is no need to make an adjustment for unequal lives.

SELF TEST

Briefly describe the replacement chain (common life) and the EAA approaches to the unequal life problem.

Is it always necessary to adjust all projects' cash flows if different projects have unequal lives? Explain.

13.7 THE OPTIMAL CAPITAL BUDGET

Thus far we have described various factors that managers consider when they evaluate individual projects. For planning purposes, managers must also forecast the total capital budget, because the amount of capital raised affects the WACC and thus influences projects' NPVs. We use Automotive Products Inc. (API), a manufacturer and distributor of auto parts, to illustrate how this process works in practice.

Step 1. The treasurer obtains an estimate of the firm's overall composite WACC. As we discussed in Chapter 10, this composite WACC is based on market conditions, the firm's capital structure, and the riskiness of its assets. API's projects are roughly similar from year to year in terms of their risks.

Step 2. The corporate WACC is scaled up or down for each of the firm's divisions to reflect the division's capital structure and risk characteristics.

API, for example, assigns a factor of 0.9 to its stable, low-risk replacement battery division, but a factor of 1.1 to its auto frame division, which sells to new car manufacturers and whose business is extremely competitive. Therefore, if the corporate cost of capital is determined to be 10.50 percent, the cost of capital for the battery division is 0.9(10.50%) = 9.45%, while that for the frame division is 1.1(10.50%) = 11.55%.

Step 3. Financial managers within each of the firm's divisions estimate the relevant cash flows and risks of each of their potential projects. The estimated cash flows should explicitly consider any embedded real options, which include opportunities to repeat the projects at a later date. Then, within each division, projects are classified into one of three groups—high risk, average risk, and low risk—and the same 0.9 and 1.1 factors are used to adjust the divisional cost of capital estimates. (A factor of 1 would be used for an average-risk project.) For example, a low-risk project in the battery division would be assigned a cost of capital of 0.9(9.45%) = 8.51%, while a high-risk project in the frame division would have a cost of 1.1(11.55%) = 12.71%.

Step 4. Each project's NPV is then determined, using its risk-adjusted cost of capital. The optimal capital budget consists of all independent projects with positive NPVs plus those mutually exclusive projects with the highest positive NPVs.

In estimating its **optimal capital budget**, we assumed that API will be able to obtain financing for all of its profitable projects. This assumption is reasonable for large, mature firms with good track records. However, smaller firms, new firms, and firms with dubious track records may have difficulties raising capital, even for projects that the firm concludes would have highly positive NPVs. In such circumstances, the size of the firm's capital budget may be constrained, a situation called **capital rationing.** In such situations capital is limited, so it should be used in the most efficient way possible. Procedures have been explored for allocating capital so as to maximize the firm's aggregate NPV subject to the constraint that the capital rationing ceiling is not exceeded. However, these procedures are extremely complicated, so they are best left for advanced finance courses.

Optimal Capital Budget
The annual investment in long-term assets that maximizes the firm's value.

Capital Rationing
The situation in which a firm can raise only a specified, limited amount of capital regardless of how many good projects it has.

The procedures discussed in this section cannot be implemented with much precision. However, they do force the firm to think carefully about each division's relative risk, about the risk of each project within the divisions, and about the relationship between the total amount of capital raised and the cost of that capital. Further, the process forces the firm to adjust its capital budget to reflect capital market conditions. If the costs of debt and equity rise, this fact will be reflected in the cost of capital used to evaluate projects, and projects that would be marginally acceptable when capital costs were low would (correctly) be ruled unacceptable when capital costs become high.

SELF TEST

Explain how a financial manager might estimate his or her firm's optimal capital budget.

What is capital rationing?

What factors must be considered when a firm is developing its optimal capital budget?

How does a firm's annual capital budget reflect market conditions?

Tying It All Together

This chapter and the previous three focused on capital budgeting. Chapter 10 described how a company estimates its cost of capital. Then, Chapter 11 described several methods used to evaluate projects. We concluded that NPV is the best single method, but IRR, MIRR, and payback all provide information that managers find useful. Next, Chapter 12 described techniques for estimating project cash flows and risk. Finally, here in Chapter 13 we discussed some topics that go beyond the simple capital budgeting framework, including the analysis of projects with real options and mutually exclusive projects with unequal lives. Chapter 13 also discussed the optimal capital budget, the relationship between the total capital budget and WACCs for individual projects, and capital rationing. We go on, in the following chapters, to discuss how the optimal capital structure is determined and the effect of this capital structure on the firm's cost of capital, on its optimal capital budget, and consequently, on its dividend policy.

SELF-TEST QUESTIONS AND PROBLEMS (Solutions Appear in Appendix A)

ST-1 **Key terms** Define each of the following terms:

a. Real option; option value
b. Abandonment option; investment timing option
c. Growth option; flexibility option
d. Replacement chain (common life)
e. Equivalent annual annuity (EAA)
f. Optimal capital budget
g. Capital rationing

ST-2 **Abandonment option** Your firm is considering a project with the following cash flows:

		PREDICTED CASH FLOW FOR EACH YEAR			
		0	1	2	3
Best case	25%	($25,000)	$18,000	$18,000	$18,000
Base case	50%	(25,000)	12,000	12,000	12,000
Worst case	25%	(25,000)	(8,000)	(8,000)	(8,000)

You learn that the firm can abandon the project, if it so chooses, after one year of operation, in which case it can sell the asset and receive $15,000 in cash at the end of Year 2. Assume that all cash flows are after-tax amounts. The WACC is 12 percent.

a. What is the project's NPV if the abandonment option is not considered?
b. What is the NPV considering abandonment?
c. What is the value of the abandonment option?

ST-3 **Projects with unequal lives** Wisconsin Dairy Co. is currently deciding on its capital budget for the upcoming year. Among the projects being considered are 2 machines, W and WW. W costs $500,000 and will produce expected after-tax cash flows of $300,000 during the next 2 years. WW also costs $500,000, but it will produce after-tax cash flows of $165,000 during the next 4 years. Both projects have a 10 percent WACC.

a. If the projects are independent and not repeatable, which project or projects should the company accept?
b. If the projects are mutually exclusive but not repeatable, which project should the company accept?
c. Assume the projects are mutually exclusive and can be repeated indefinitely.
   (1) Use the replacement chain method to determine the NPV of the project selected.
   (2) Use the equivalent annual annuity method to determine the annuity of the project selected.
d. Could a replacement chain analysis be modified for use where the project's cash flows are different each time it is repeated? Explain.

QUESTIONS

13-1 Explain in general terms what each of the following real options is and how it could change projects' NPVs, relative to what would have been estimated if the options were not considered, and their corresponding risk.

a. Abandonment.
b. Timing.
c. Growth.
d Flexibility.

13-2 Would a failure to recognize growth options cause a firm's actual capital budget to be above or below the optimal level? Would your answer be the same for abandonment, timing, and flexibility options? Explain.

13-3 Companies often have to increase their investment costs to obtain real options. Why might this be so, and how could a firm decide if it was worth the cost to obtain a given real option?

13-4 What's a "replacement chain?" When and how are replacement chains used in capital budgeting?

13-5 What's an "equivalent annual annuity (EAA)?" When and how are EAAs used in capital budgeting?

13-6 Suppose a firm is considering two mutually exclusive projects. One has a life of 6 years and the other a life of 10 years. Both projects can be repeated at the end of their lives. Might the failure to employ a replacement chain or EAA analysis bias the decision toward one of the projects? If so, which one, and why?

13-7 How might the corporate WACC be affected by the size of a firm's capital budget?

13-8 What is capital rationing?

PROBLEMS

Easy Problems 1–5

13-1 **Growth option** Martin Development Co. is deciding whether to proceed with Project X. The cost would be $9 million in Year 0. There is a 50 percent chance that X would be hugely successful and would generate annual after-tax cash flows of $6 million per year during Years 1, 2, and 3. However, there is a 50 percent chance that X would be less successful and would generate only $1 million per year for the 3 years. If Project X is hugely successful, it would open the door to another investment, Project Y, that would require a $10 million outlay at the end of Year 2. Project Y would then be sold to another company at a price of $20 million at the end of Year 3. Martin's WACC is 11 percent.

a. If the company does not consider real options, what is Project X's NPV?
b. What is X's NPV considering the growth option?
c. How valuable is the growth option?

13-2 **Projects with unequal lives** Haley's Graphic Designs Inc. is considering two mutually exclusive projects. Both require an initial investment of $10,000, and their risks are average for the firm. Project A has an expected life of 2 years with after-tax cash inflows of $6,000 and $8,000 at the end of Years 1 and 2, respectively. Project B has an expected life of 4 years with after-tax cash inflows of $4,000 at the end of each of the next 4 years. The firm's WACC is 10 percent.

a. If the projects cannot be repeated, which project should be selected if Haley uses NPV as its criterion for project selection?
b. Assume the projects can be repeated and that there are no anticipated changes in the cash flows. Use the replacement chain analysis to determine the NPV of the project selected.
c. Make the same assumptions in part b. Use the equivalent annual method to determine the annuity of the project selected.

13-3 **Replacement chain** Cotner Clothes Inc. is considering the replacement of its old, fully depreciated knitting machine. Two new models are available: Machine 190-3, which has a cost of $190,000, a 3-year expected life, and after-tax cash flows (labor savings and depreciation) of $87,000 per year; and Machine 360-6, which has a cost of $360,000, a 6-year life, and after-tax cash flows of $98,300 per year. Assume that both projects can be repeated. Knitting machine prices are not expected to rise, because inflation will be offset by cheaper components (microprocessors) used in the machines. Assume that Cotner's WACC is 14 percent. Should the firm replace its old knitting machine, and, if so, which new machine should it use?

13-4 **Equivalent annual annuity** Corcoran Consulting is deciding which of two computer systems to purchase. They can purchase state-of-the-art equipment (System A) for $20,000, which will generate cash flows of $6,000 at the end of each of the next 6 years. Alternatively, they can spend $12,000 for equipment that can be used for 3 years and generates cash flows of $6,000 at the end of each year (System B). If the company's WACC is 10 percent and both "projects" can be repeated indefinitely, which system should be chosen and what is its EAA?

13-5 **Optimal capital budget** Marble Construction estimates that its WACC is 10 percent if equity comes from retained earnings. However, if the company issues new stock to raise new equity, it estimates that its WACC will rise to 10.8 percent. The company believes that it will exhaust its retained earnings at $2,500,000 of capital due to the number of highly profitable projects available to the firm and its limited earnings. The company is considering the following seven investment projects:

Project	Size	IRR
A	$ 650,000	14.0%
B	1,050,000	13.5
C	1,000,000	11.2
D	1,200,000	11.0
E	500,000	10.7
F	650,000	10.3
G	700,000	10.2

Assume that each of these projects is independent and that each is just as risky as the firm's existing assets. Which set of projects should be accepted, and what is the firm's optimal capital budget?

Intermediate Problems 6–9

13-6 **Replacement chain** Zappe Airlines is considering two alternative planes. Plane A has an expected life of 5 years, will cost $100 million, and will produce net cash flows of $30 million per year. Plane B has a life of 10 years, will cost $132 million, and will produce net cash flows of $25 million per year. Zappe plans to serve the route for 10 years. The company's WACC is 12 percent. If Zappe needs to purchase a new Plane A, the cost will be $105 million, but cash inflows will remain the same. Should Zappe acquire Plane A or Plane B? Explain your answer.

13-7 **Replacement chain** The Fernandez Company has the opportunity to invest in one of two mutually exclusive machines that will produce a product it will need for the next 8 years. Machine A costs $10 million but would provide after-tax inflows of $4 million per year for 4 years. If Machine A were replaced, its cost would be $12 million due to inflation, and its cash inflows would increase to $4.2 million due to production efficiencies.

Machine B costs $15 million and would provide after-tax inflows of $3.5 million per year for 8 years. If the WACC is 10 percent, which machine should be acquired?

13-8 **Equivalent annual annuity** A firm has two mutually exclusive investment projects to evaluate. The projects have the following cash flows:

Time	Project X	Project Y
0	($100,000)	($70,000)
1	30,000	30,000
2	50,000	30,000
3	70,000	30,000
4	—	30,000
5	—	10,000

Projects X and Y are equally risky and may be repeated indefinitely. If the firm's WACC is 12 percent, what is the EAA of the project that adds the most value to the firm? (Round your final answer to the nearest whole dollar.)

13-9 **Investment timing option** Digital Inc. is considering production of a new cell phone. The project would require an investment of $20 million. If the phone were well received, then the project would produce cash flows of $10 million a year for 3 years, but if the market did not like the product, then the cash flows would be only $5 million per year. There is a 50 percent probability of both good and bad market conditions. Digital could delay the project for a year while it conducts a test to determine if demand would be strong or weak. The delay would not affect either the project's cost or its cash flows. Digital's WACC is 10 percent. What action would you recommend?

Challenging Problems 10–13

13-10 **Abandonment option** The Scampini Supplies Company recently purchased a new delivery truck. The new truck costs $22,500, and it is expected to generate after-tax cash flows, including depreciation, of $6,250 per year. The truck has a 5-year expected life. The expected year-end abandonment values (salvage values after tax adjustments) for the truck are given here. The company's WACC is 10 percent.

Year	Annual After-Tax Cash Flow	Abandonment Value
0	($22,500)	—
1	6,250	$17,500
2	6,250	14,000
3	6,250	11,000
4	6,250	5,000
5	6,250	0

a. Should the firm operate the truck until the end of its 5-year physical life; if not, what is its optimal economic life?

b. Would the introduction of abandonment values, in addition to operating cash flows, ever *reduce* the expected NPV and/or IRR of a project? Explain.

13-11 **Optimal capital budget** Hampton Manufacturing estimates that its WACC is 12 percent if equity comes from retained earnings. However, if the company issues new stock to raise new equity, it estimates that its WACC will rise to 12.5 percent. The company believes that it will exhaust its retained earnings at $3,250,000 of capital due to the number of highly profitable projects available to the firm and its limited earnings. The company is considering the following 7 investment projects:

Project	Size	IRR
A	$ 750,000	14.0%
B	1,250,000	13.5
C	1,250,000	13.2
D	1,250,000	13.0
E	750,000	12.7
F	750,000	12.3
G	750,000	12.2

a. Assume that each of these projects is independent and that each is just as risky as the firm's existing assets. Which set of projects should be accepted, and what is the firm's optimal capital budget?

b. Now, assume that Projects C and D are mutually exclusive. Project D has an NPV of $400,000, whereas Project C has an NPV of $350,000. Which set of projects should be accepted, and what is the firm's optimal capital budget?

c. Ignore part b, and now assume that each of the projects is independent but that management decides to incorporate project risk differentials. Management judges Projects B, C, D, and E to have average risk, Project A to have high risk, and Projects F and G to have low risk. The company adds 2 percent to the WACC of those projects that are significantly more risky than average, and it subtracts 2 percent from the WACC for those that are substantially less risky than average. Which set of projects should be accepted, and what is the firm's optimal capital budget?

13-12 **Investment timing option** The Bush Oil Company is deciding whether to drill for oil on a tract of land that the company owns. The company estimates that the project would cost $8 million today. Bush estimates that once drilled, the oil will generate positive net cash flows of $4 million a year at the end of each of the next 4 years. While the company is fairly confident about its cash flow forecast, it recognizes that if it waits 2 years, it would have more information about the local geology as well as the price of oil. Bush estimates that if it waits 2 years, the project would cost $9 million. Moreover, if it waits 2 years, there is a 90 percent chance that the net cash flows would be $4.2 million a year for 4 years, and there is a 10 percent chance that the cash flows would be $2.2 million a year for 4 years. Assume that all cash flows are discounted at 10 percent.

a. If the company chooses to drill today, what is the project's net present value?
b. Would it make sense to wait 2 years before deciding whether to drill? Explain.
c. What is the value of the investment timing option?
d. What disadvantages might arise from delaying a project like this drilling project?

13-13 **Real options** Nevada Enterprises is considering buying a vacant lot that sells for $1.2 million. If the property is purchased, the company's plan is to spend another $5 million today ($t = 0$) to build a hotel on the property. The after-tax cash flows from the hotel will depend critically on whether the state imposes a tourism tax in this year's legislative session. If the tax is imposed, the hotel is expected to produce after-tax cash inflows of $600,000 at the end of each of the next 15 years. If the tax is not imposed, the hotel is expected to produce after-tax cash inflows of $1,200,000 at the end of each of the next 15 years. The project has a 12 percent WACC. Assume at the outset that the company does not have the option to delay the project.

a. What is the project's expected NPV if the tax is imposed?
b. What is the project's expected NPV if the tax is not imposed?
c. Given that there is a 50 percent chance that the tax will be imposed, what is the project's expected NPV if they proceed with it today?
d. While the company does not have an option to delay construction, it does have the option to abandon the project 1 year from now if the tax is imposed. If it abandons the project, it would sell the complete property 1 year from now at an expected price of $6 million. Once the project is abandoned the company would no longer receive any cash inflows from it. Assuming that all cash flows are discounted at 12 percent, would the existence of this abandonment option affect the company's decision to proceed with the project today? Explain.
e. Finally, assume that there is no option to abandon or delay the project, but that the company has an option to purchase an adjacent property in 1 year at a price of $1.5 million. If the tourism tax is imposed, the net present value of developing this property (as of $t = 1$) is only $300,000 (so it wouldn't make sense to purchase the property for $1.5 million). However, if the tax is not imposed, the net present value of the future opportunities from developing the property would be $4 million (as of $t = 1$). Thus, under this scenario it would make sense to purchase the property for $1.5 million. Assume that these cash flows are discounted at 12 percent and the probability that the tax will be imposed is still 50 percent. How much would the company pay today for the option to purchase this property 1 year from now for $1.5 million?

COMPREHENSIVE/SPREADSHEET PROBLEMS

13-14 **Real options** Use a spreadsheet model to evaluate the project analyzed in Problem 13-13.

13-15 **Real options** Bankers' Services Inc. (BSI) is considering a project that has a cost of $10 million and an expected life of 3 years. There is a 30 percent probability of good conditions, in which case the project will provide a cash flow of $9 million at the end of each year for 3 years. There is a 40 percent probability of average conditions, in which case the annual cash flows will be $4.5 million, and there is a 30 percent probability of bad conditions and a cash flow of −$1.5 million per year. BSI can, if it chooses, close down the project at the end of any year and sell the related assets for 90 percent of the book value. The asset sale price will be received at the end of the year the project is shut down. The related assets will be depreciated by the straight-line method over 3 years, and the value at the end of Year 3 is zero. (Don't worry about IRS regulations for this problem.) BSI uses a 12 percent WACC to evaluate projects like this.

a. Find the project's expected NPV with and without the abandonment option.
b. How sensitive is the NPV to changes in the company's WACC? To the percentage of book value at which the asset can be sold?
c. Now assume that the project cannot be shut down. However, expertise gained by taking it on will lead to an opportunity at the end of Year 3 to undertake a venture that would have the same cost as the original project, and would be undertaken if the best-case scenario developed. If the project is wildly successful (the good conditions), the firm will go ahead with the project, but it will not go ahead if the other two scenarios occur (because consumer demand will still be considered too difficult to determine). As a result, the new project would generate the same cash flows as the original project in the best-case scenario. In other words, there would be a second $10 million cost at the end of Year 3, and then cash flows of $9 million for the following 3 years. This new project could also not be abandoned if it is undertaken. How does this new information affect the original project's expected NPV? At what WACC would the project break even in the sense that NPV = $0?
d. Now suppose the original (no abandonment) project could be delayed a year. All the cash flows would remain unchanged, but information obtained during that year would tell the company exactly which set of demand conditions existed. How does this option to delay the project affect its NPV?

Integrated Case

21st Century Educational Products

13-16 Other topics in capital budgeting 21st Century Educational Products is a rapidly growing software company, and, consistent with its growth, it has a relatively large capital budget. While most of the company's projects are fairly easy to evaluate, a handful of projects involve more complex evaluations.

John Keller, a senior member of the company's finance staff, coordinates the evaluation of these more complex projects. His group brings their recommendations directly to the company's CFO and CEO, Kristin Riley and Bob Stevens, respectively.

a. In recent months, Keller's group has begun to focus on real option analysis.
   (1) What is real option analysis?
   (2) What are some examples of projects with embedded real options?
b. Considering real options, one of Keller's colleagues, Barbara Hudson, has suggested that instead of investing in Project X today, it might make sense to wait a year because 21st Century would learn a lot more about market conditions and would be better able to forecast the project's cash flows. Right now, 21st Century forecasts that Project X, which will last 4 years, will generate expected annual net cash flows of $33,500. However, if the company waits a year, it will learn more about market conditions. There is a 50 percent chance that the market will be strong and a 50 percent chance it will be weak. If the market is strong, the annual cash flows will be $43,500. If the market is weak, the annual cash flows will be only $23,500. If 21st Century chooses to wait a year, the initial investment will remain $100,000. Assume that all cash flows are discounted at 10 percent. Should 21st Century invest in Project X today, or should it wait a year before deciding whether to invest in the project?
c. Now let's assume that there is more uncertainty about the future cash flows. More specifically, assume that the annual cash flows are now $53,500 if the market is strong and $13,500 if the market is weak. Assume that the up-front cost is still $100,000 and that the WACC is still 10 percent. Will this increased uncertainty make the firm more or less willing to invest in the project today?

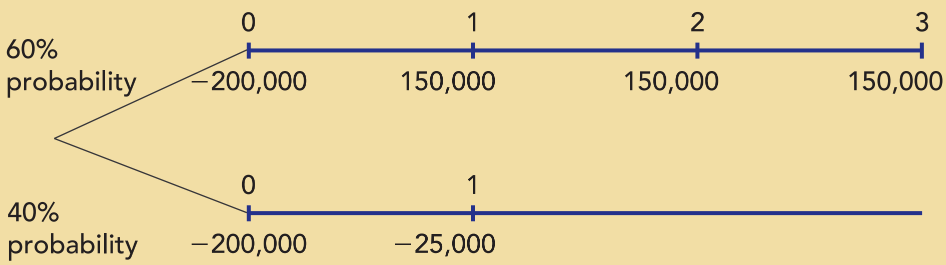
d. 21st Century is considering another project, Project Y. Project Y has an up-front cost of $200,000 and an economic life of 3 years. If the company develops the project, its after-tax operating costs will be $100,000 a year; however, the project is expected to produce after-tax cash inflows of $180,000 a year. Thus, the project's estimated cash flows are as follows:

Year	Cash Outflows	Cash Inflows	Net Cash Flows
0	($200,000)	$ 0	($200,000)
1	(100,000)	180,000	80,000
2	(100,000)	180,000	80,000
3	(100,000)	180,000	80,000

(1) The project has an estimated WACC of 10 percent. What is the project's NPV?

(2) While the project's operating costs are fairly certain at $100,000 per year, the estimated cash inflows depend critically on whether 21st Century's largest customer uses the product. Keller estimates that there is a 60 percent chance the customer will use the product, in which case the project will produce after-tax cash inflows of $250,000. Thus, its net cash flows would be $150,000 per year. However, there is a 40 percent chance the customer will not use the product, in which case the project will produce after-tax cash inflows of only $75,000. Thus, its net cash flows would be −$25,000. Write out the estimated cash flows, and calculate the project's NPV under each of the two scenarios.

(3) While 21st Century does not have the option to delay the project, it will know 1 year from now if the key customer has selected the product. If the customer chooses not to adopt the product, 21st Century has the option to abandon the project. If it abandons the project, it will not receive any cash flows after Year 1, and it will not incur any operating costs after Year 1. Thus, if the company chooses to abandon the project, its estimated cash flows are as follows:



Again, assuming a WACC of 10 percent, what is the project's expected NPV if it abandons the project? Should 21st Century invest in Project Y today, realizing it has the option to abandon the project at t = 1?

(4) Up until now we have assumed that the abandonment option has not affected the project's WACC. Is this assumption reasonable? How might the abandonment option affect the WACC?

e. 21st Century is also considering Project Z. Project Z has an up-front cost of $500,000, and it is expected to produce after-tax cash inflows of $100,000 at the end of each of the next 5 years (t = 1, 2, 3, 4, and 5). Because Project Z has a WACC of 12 percent, it clearly has a negative NPV. However, Keller and his group recognize that if 21st Century goes ahead with Project Z today, there is a 10 percent chance that this will lead to subsequent opportunities that have a net present value at t = 5 equal to $3,000,000. At the same time, there is a 90 percent chance that the subsequent opportunities will have a negative net present value (−$1,000,000) at t = 5. On the basis of their knowledge of real options, Keller and his group understand that the company will choose to develop these subsequent opportunities only if they appear to be profitable at t = 5. Given this information, should 21st Century invest in Project Z today?

f. Keller's group is looking at a variety of other interesting projects. For example, the group has been asked to choose between the following two mutually exclusive projects:

	EXPECTED NET CASH FLOWS	
Year	**Project S**	**Project L**
0	($100,000)	($100,000)
1	59,000	33,500
2	59,000	33,500
3	—	33,500
4	—	33,500

Both projects may be repeated and both are of average risk, so they should be evaluated at the firm's WACC, 10 percent. Using both the replacement chain and equivalent annual annuity methods, which project should be chosen?

cyberproblem

Please go to the ThomsonNOW Web site to access the Cyberproblems.