Chapter 14
Real Options and Other Topics in Capital Budgeting

Learning Objectives

After reading this chapter, the student should be able to:

- Explain what real options are, how they influence capital budgeting, and how they can be analyzed.
- Discuss how projects' NPVs are affected by the size of the firm's total capital budget, the process involved in determining a firm's capital budget, and the analysis undertaken in selecting value-maximizing projects.
- Describe the post-audit, which is an important part of the capital budgeting process, and discuss its relevance in capital budgeting decisions.

Lecture Suggestions

This chapter covers some important but relatively technical topics. Note too that this chapter is more modular than most, i.e., the major sections are discrete, hence they can be omitted without loss of continuity. Therefore, if you are experiencing a time crunch, you could skip sections or even the entire chapter.

What we cover, and the way we cover it, can be seen by scanning the slides and Integrated Case solution for Chapter 14, which appears at the end of this chapter solution. For other suggestions about the lecture, please see the "Lecture Suggestions" in Chapter 2, where we describe how we conduct our classes.

DAYS ON CHAPTER: 2 OF 56 DAYS (50-MINUTE PERIODS)

Answers to End-of-Chapter Questions

14-1 **a.** An abandonment option is the option to stop a project if operating cash flows turn out to be lower than expected. This option can both raise expected profitability and lower project risk, because in the case of poor cash flows, the project can be ended and rather than continue realizing negative cash flows, fixed assets are sold and some cash is recovered.

b. An investment timing option occurs when a firm has the option of delaying the start of a project until additional information can be obtained. After the delay, if conditions for the project look unfavorable, the project will not be undertaken, while if conditions are favorable then the project proceeds as usual. However, there are some drawbacks to relying on investment timing options. First, the timing option should raise NPV because the probability of bad returns is less, but that NPV needs to be discounted back one additional year. Second, there might be valuable "first mover" advantages to a project that will be lost if the project is delayed a year.

c. Growth options exist if an investment creates the opportunity to make other potentially profitable investments that would not otherwise be possible. A common example of a growth option occurs when a firm starts a project in a new country or market. While it is hoped that the project will add value from its cash flows, it also has value because it opens the door to other opportunities for the firm in the new country/market.

d. Flexibility options permit the firm to alter operations depending on how conditions change during the project's life. Typically, inputs, outputs, or both can be changed easily to respond to market demands. For example, instead of building an auto factory that builds a specific type of car (compact, SUV, etc.), a manufacturer can build a factory that allows the building of many types of cars. Therefore, as market demand and consumer tastes change the firm can rapidly respond.

14-2 Failure to recognize a growth option implies that a project with a negative conventional NPV was rejected despite having an embedded growth option whose consideration would cause the NPV to be positive. As a result, failure to recognize the value of a growth option implies that the capital budget is below the optimal level since a value-adding project (albeit because of a real option) has been rejected. This argument holds when considering the failure to recognize all real options.

14-3 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 might require contractual arrangements with suppliers, customers, and its union, and there might be some costs in obtaining the advanced permissions. Any such costs could be compared with the value of the option, and this could enter into the initial decision. In the case of investment timing options, the initial investment might grow if the project is delayed. For any type of options, these additional costs must be considered in the analysis and the benefits of the "real option" must outweigh the associated costs.

14-4 For large, mature firms with good track records we can assume that all of its profitable projects can be financed, but this assumption is harder to make for smaller firms, new firms, and firms with dubious track records. These firms may have difficulties raising capital, even for projects that the firm concludes would have 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

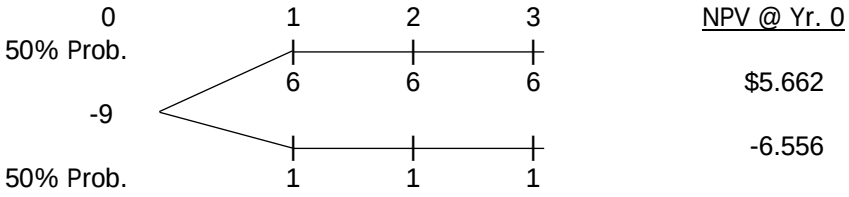
capital rationing ceiling is not exceeded. As a result the greater the capital budget, the greater the need for external financing, which raises the WACC.

14-5 The post-audit is a comparison of actual versus expected results for a given capital project. The post-audit has two main purposes: (1) improve forecasts and (2) improve operations.

The post-audit is not a simple, mechanical process. First, we must recognize that each element of the cash flow forecast is subject to uncertainty; so a percentage of all projects undertaken by any reasonably aggressive firm will necessarily go awry. This fact must be considered when the performances of the operating executives who sponsor projects are appraised. Second, projects sometimes fail to meet expectations for reasons beyond the control of their sponsors and for reasons that no one could be expected to anticipate. Third, it is often difficult to separate the operating results of one investment from those of a larger system. Fourth, it is often difficult to hand out blame or praise because the executives who were responsible for launching a given investment have moved on by the time the results are known.

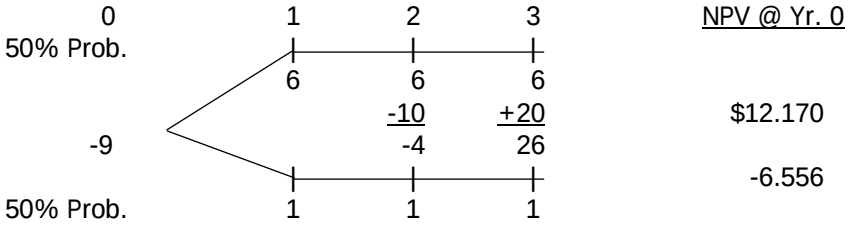
Solutions to End-of-Chapter Problems

14-1 **a.** WACC = 11%; cash flows shown in millions.



Expected NPV = 0.5($5.662) + 0.5(-$6.556) = -$0.447 million. The project would not be done.

b. If the project is hugely successful, $10 million will be spent at the end of Year 2, and the new venture will be sold for $20 million at the end of Year 3.



Expected NPV = 0.5($12.170) + 0.5(-$6.556) = $2.807 million.

c. Value of growth option:

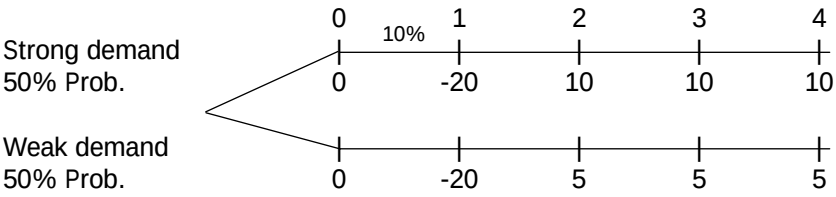
NPV with option	$2.807 million
NPV without option	- 0.000
	+$2.807 million

14-2 The firm should accept Projects A, B, C, and D. The firm's optimal capital budget is $3,900,000 at a WACC of 10.8% and it requires the firm to issue new common stock.

14-3 Cash flows shown in millions on time line:

NPV = -$1.349 million.

Wait 1 year; cash flows shown in millions on time line:



However, if demand is weak, the project's NPV is negative and therefore would not be undertaken. The value of this option of waiting one year is evaluated as 0.5($0) + (0.5)($4.426) = $2.213 million. Since the NPV of waiting one year is positive and greater than going ahead and proceeding with the project today, it makes sense to wait.

14-4 **a.** NPV of abandonment after Year t:

Using a financial calculator, input the following: $CF_0 = -22500$, $CF_1 = 23750$, and I/YR = 10 to solve for $NPV_1 = -\$909.09 \approx -\$909$.

Using a financial calculator, input the following: $CF_0 = -22500$, $CF_1 = 6250$, $CF_2 = 20250$, and I/YR = 10 to solve for $NPV_2 = -\$82.64 \approx -\$83$.

Using a financial calculator, input the following: $CF_0 = -22500$, $CF_1 = 6250$, $N_j = 2$, $CF_3 = 17250$, and I/YR = 10 to solve for $NPV_3 = \$1,307.29 \approx \$1,307$.

Using a financial calculator, input the following: $CF_0 = -22500$, $CF_1 = 6250$, $N_j = 3$, $CF_4 = 11250$, and I/YR = 10 to solve for $NPV_4 = \$726.73 \approx \$727$.

Using a financial calculator, input the following: $CF_0 = -22500$, $CF_1 = 6250$, $N_j = 5$, and I/YR = 10 to solve for $NPV_5 = \$1,192.42 \approx \$1,192$.

The firm should operate the truck for 3 years, $NPV_3 = \$1,307$.

b. No. Abandonment possibilities could only raise NPV and IRR. The value of the firm is maximized by abandoning the project after Year 3.

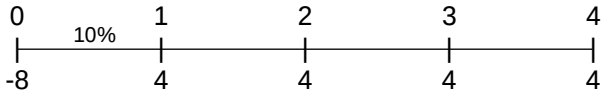
14-5 **a.** WACC = 12.5%.

Since each project is independent and of average risk, all projects whose IRR > WACC will be accepted. Consequently, Projects A, B, C, D, and E will be accepted and the optimal capital budget is $5,250,000.

b. If Projects C and D are mutually exclusive, the firm will select Project D rather than Project C, because Project D's NPV is greater than Project C's NPV. So, the optimal capital budget is now $4 million, and consists of Projects A, B, D, and E.

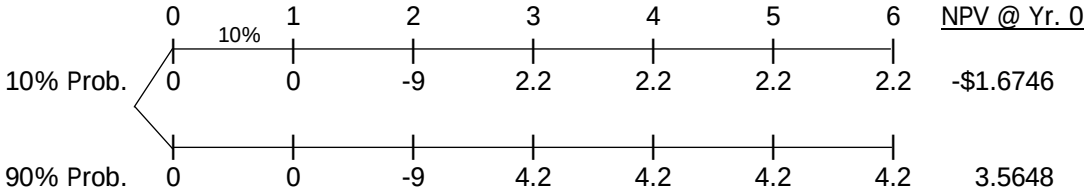
c. The appropriate costs of capital are 10.5% for low-risk projects, 12.5% for average-risk projects, and 14.5% for high-risk projects. Since Project A is high risk, it will be rejected (IRR = 14% < WACC = 14.5%). Projects B, C, D, and E are all average risk and will be accepted since their returns exceed 12.5%. Projects F and G are low risk and will both be accepted since their returns exceed 10.5%. Therefore, the optimal capital budget is $6 million and consists of Projects B, C, D, E, F, and G.

14-6 **a.**



NPV = $4.6795 million.

b. Wait 2 years:



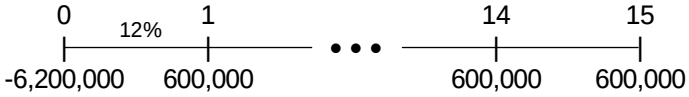
If the cash flows are only $2.2 million, the NPV of the project is negative and, thus, would not be undertaken. The value of the option of waiting two years is evaluated as 0.10($0) + 0.90($3.5648) = $3.2083 million.

Since the NPV of waiting two years is less than going ahead and proceeding with the project today, it makes sense to drill today.

c. The investment timing option has a value of $0. Since the difference between the project with the option and the project without the option is negative, $3.2083 million – $4.6795 million = -$1.4712 million, the option will not be exercised. In other words, the costs of delaying the project outweigh the benefits gained by delaying and gathering more information.

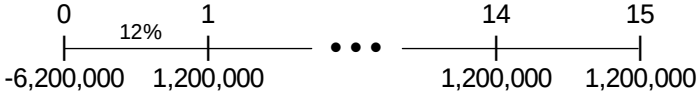
d. There is a danger that oil prices will decline causing the company to receive lower revenues for the oil it extracts, and there is a danger that the company will lose market share or the chance to compete for new contracts as a result of waiting.

14-7 **a.** Cash flows if tax imposed:



Using a financial calculator, input the following data: CF_0 = -6200000; CF_{1-15} = 600000; I/YR = 12; and then solve for NPV = -$2,113,481.31.

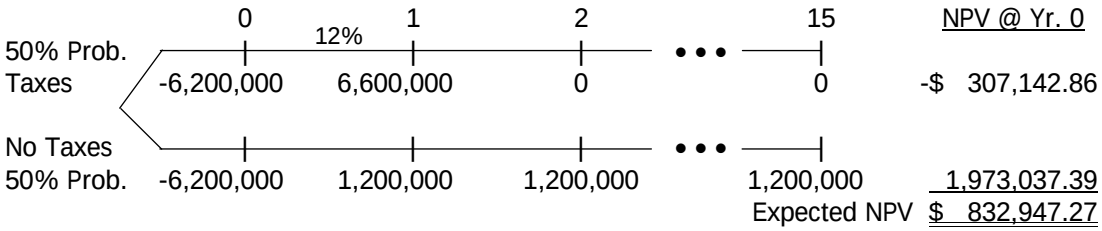
b. Cash flows if tax not imposed:



Using a financial calculator, input the following data: CF_0 = -6200000; CF_{1-15} = 1200000; I/YR = 12; and then solve for NPV = $1,973,037.39.

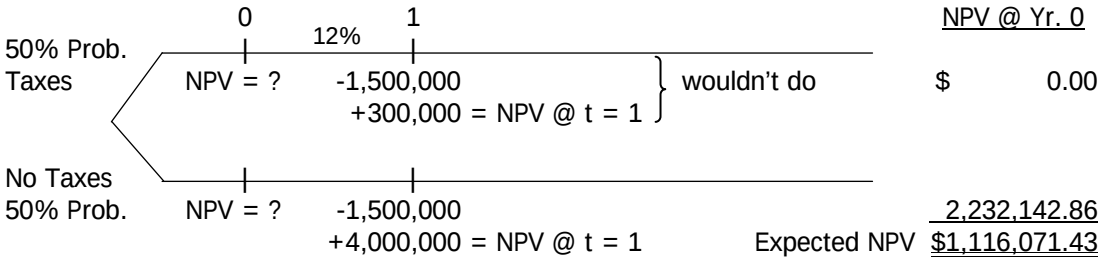
c. If they proceed with the project today, the project's expected NPV = (0.5 × -$2,113,481.31) + (0.5 × $1,973,037.39) = -$70,221.96. So, Nevada Enterprises would not do it.

d. Since the project's NPV with the tax is negative, if the tax were imposed the firm would abandon the project. Thus, the decision tree looks like this:



Yes, the existence of the abandonment option changes the expected NPV of the project from negative to positive. Given this option the firm would take on the project because its expected NPV is $832,947.27.

e.



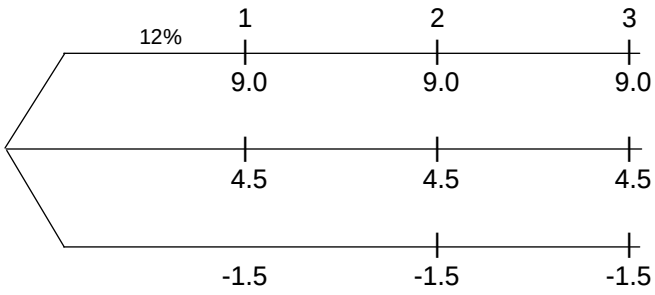
If the firm pays $1,116,071.43 today for the option to purchase the land, then the NPV of the project is exactly equal to zero. So the firm would not pay any more than this for the option.

Comprehensive/Spreadsheet Problems

Note to Instructors:
The solutions to these problems are <u>not</u> provided to students at the back of their text. Instructors can access the *Excel* files on the textbook's web site or the Instructor's Resource CD.

14-8 See Problem 14-7 on the preceding two pages.

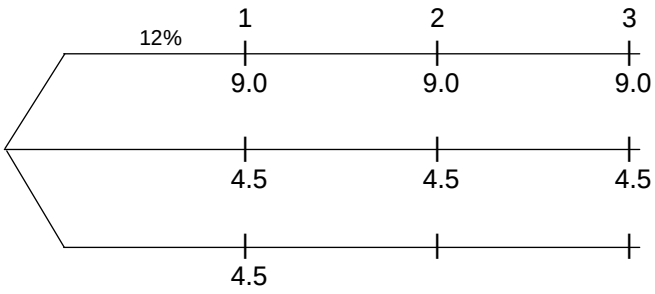
14-9 **a.** Without abandonment (Cost @ t = 0 = -$10 million):



Expected NPV = 0.3($11.62) + 0.4($0.81) + 0.3(-$13.60) = -$0.27 million.
Standard deviation = $9.81 million.
Coefficient of variation = 35.98.

With abandonment (Cost @ t = 0 = -$10 million):

After the first year, the fixed assets will be depreciated by 1/3 of their value, meaning they are worth $6.67 million and can be retired/sold for $6.00 million. The cash flow in the abandonment branch reflects the -$1.5 million operating cash flow plus the retirement of fixed assets (-$1.5 million + $6 million).



Expected NPV = 0.3($11.62) + 0.4($0.81) + 0.3(-$5.98) = $2.01 million.
Standard deviation = $6.89 million.
Coefficient of variation = 3.42.

When the abandonment option is factored in, the very large negative NPV under bad conditions is reduced, and the expected NPV becomes positive. Also, the standard deviation and CV decline, indicating that the abandonment option lowers the project's risk.

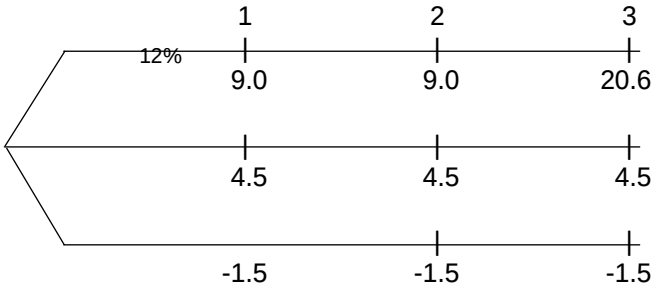
b.

WACC	% of Book Value the Assets are sold at							
	$2.01	63%	72%	81%	90%	99%	108%	117%
	8.4%	$2.26	$2.43	$2.59	$2.76	$2.93	$3.09	$3.26
	9.6%	$2.01	$2.17	$2.34	$2.50	$2.67	$2.83	$2.99
	10.8%	$1.77	$1.93	$2.09	$2.25	$2.42	$2.58	$2.74
	12.0%	$1.53	$1.69	$1.85	$2.01	$2.17	$2.34	$2.50
	13.2%	$1.30	$1.46	$1.62	$1.78	$1.94	$2.10	$2.26
	14.4%	$1.09	$1.24	$1.40	$1.56	$1.72	$1.87	$2.03
	15.6%	$0.87	$1.03	$1.19	$1.34	$1.50	$1.65	$1.81

NPV declines as the WACC increases, and it increases as the percentage of book at which the asset can be sold increases. However, if the WACC is reasonably close to the estimated 12%, and the sale percentage is close to the estimated 90%, then the NPV will be comfortably positive.

Conclusion: When abandonment is recognized, the project is acceptable.

c. Without abandonment, with growth (Cost @ t = 0 = -$10 million)

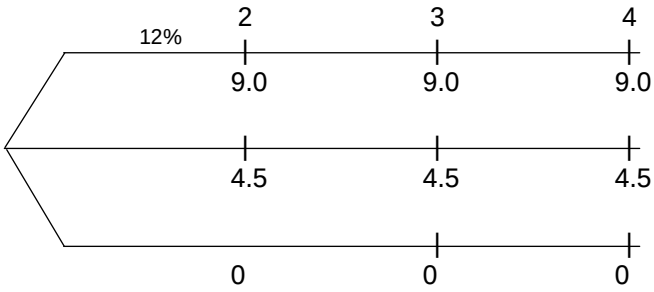


	1	2	3	NPV @ Yr. 0
30% Prob. Good	9.0	9.0	20.6	$19.88
40% Prob. Average	4.5	4.5	4.5	0.81
30% Prob. Bad	-1.5	-1.5	-1.5	-13.60

Expected NPV = 0.3($19.88) + 0.4($0.81) + 0.3(-$13.60) = $2.21 million.
Standard deviation = $13.02 million.
Coefficient of variation = 5.90.

This growth option makes the project's NPV positive, too. Using a spreadsheet, the WACC at which NPV equals zero in this case is 23.11%. So, we can be safe in saying that this project's NPV is robust to changes in the WACC.

d. Without abandonment, with investment timing (Cost @ t = 0 = -$10 million)



	2	3	4	NPV @Yr. 1
30% Prob. Good	9.0	9.0	9.0	$11.62
40% Prob. Average	4.5	4.5	4.5	0.81
30% Prob. Bad	0	0	0	0

Expected NPV @ Year 1 = 0.3($11.62) + 0.4($0.81) + 0.3(0) = $3.81 million.
Expected NPV today = $3.81/1.12 = $3.40 million.

The option value is calculated as follows:

NPV without abandonment but with timing option:	$3.40
NPV without abandonment and timing option:	$0.00
Option value	$3.40

Integrated Case

14-10
21st Century Educational Products
Other Topics in Capital Budgeting

21st Century Educational Products (21st Century) 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 focused on real option analysis.

(1) What is real option analysis?

Answer: [Show S14-1 and S14-2 here.] Real options exist when managers can influence the size and riskiness of a project's cash flows by taking different actions during or at the end of a project's life.

Real option analysis incorporates typical NPV capital budgeting analysis with an analysis of opportunities resulting from managers' responses to changing circumstances that can influence a project's outcome.

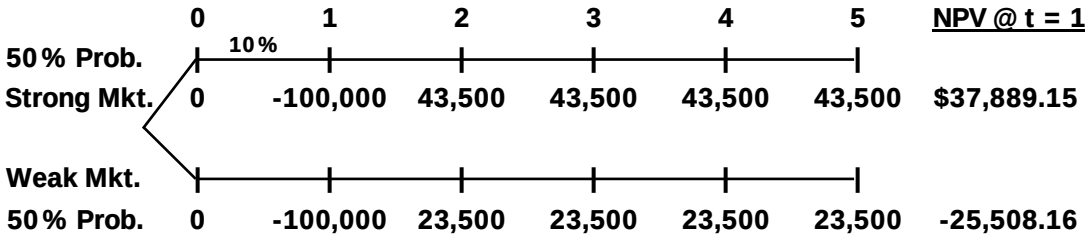
A. (2) What are some examples of projects with real options?

Answer: [Show S14-3 here.] A project may contain one or more different types of real options. Examples include abandonment/shutdown options,

investment timing options, growth/expansion options, and flexibility 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 one year because 21st Century would learn more about market conditions and would improve its forecast of the project's cash flows. Right now 21st Century forecasts that Project X will generate expected cash flows of $33,500 for 4 years. However, if the company waits one year, it will learn more about market conditions. There is a 50% chance that the market will be strong and a 50% chance that 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 one year, the initial investment will remain $100,000 and cash flows will continue for 4 years after the initial investment is made. Assume that all cash flows are discounted at 10%. Should 21st Century invest in Project X today, or should it wait a year before deciding whether to invest in the project?**

Answer: **[Show S14-4 through S14-7 here.]**

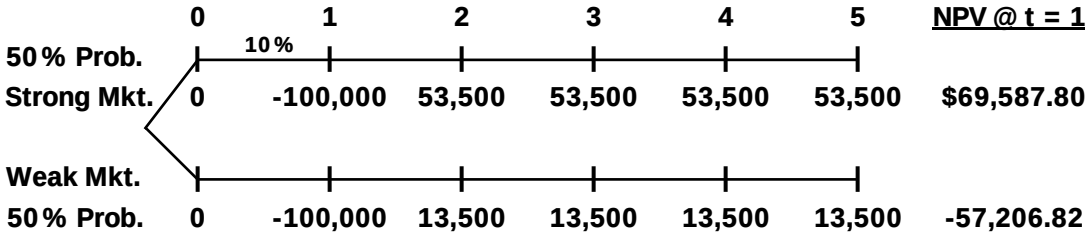


However, in a weak market the firm will not undertake Project X since its NPV < 0. Consequently, the expected NPV of waiting one year is (0.5)$0 + (0.5)($37,889.15) = $18,944.58. However, this is the present value at Year 1, so we must discount it back one year to find

the value today of waiting to do Project X. So, the value today of waiting is calculated as $18,944.58/1.10 = $17,222.34. Therefore, the firm should wait to obtain more information about the market rather than undertaking Project X today because the NPV is $17,222.34 compared to $6,190.49, the NPV of doing it today.

C. Now assume that there is more uncertainty about the future cash flows. More specifically, assume that the annual cash flows are $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%. Will this increased uncertainty make the firm more or less willing to invest in the project today? Explain.

Answer: [Show S14-8 and S14-9 here.]



In a weak market the firm will not undertake Project X since its NPV < 0. Consequently, the expected NPV of waiting one year is (0.5)$0 + (0.5)($69,587.80) = $34,793.90. However, this is the present value at Year 1, so we must discount it back one year to find the value today of waiting to do Project X. So, the value today of waiting is calculated as $34,793.90/1.10 = $31,630.82. Therefore, the firm should wait to obtain more information about the market rather than undertaking Project X today because the NPV is $31,630.82 compared to $6,190.49, the NPV of doing it today.

The more variable the cash flows (the more uncertainty) the less willing the firm will be to invest in the project today.

Factors the firm should consider in decision of when to invest:

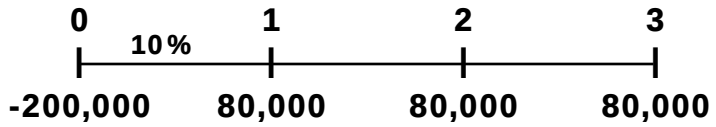
1. **Delaying the project means that cash flows come later rather than sooner.**
2. **It might make sense to proceed today if there are important advantages to being the first competitor to enter a market.**
3. **Waiting may allow you to take advantage of changing conditions.**

D. **21st Century is considering another project, Project Y. Project Y has an up-front cost of $200,000 and an economic life of three 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	Estimated Project 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%. What is the project's NPV?

Answer: **[Show S14-10 here.]**

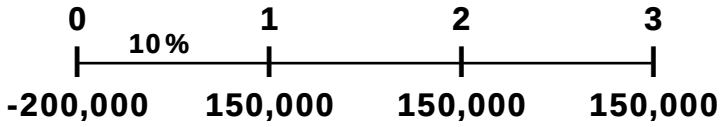


Using a financial calculator, input the following data: $CF_0 = -200000$; $CF_{1-3} = 80000$; I/YR = 10; and then solve for NPV = -$1,051.84.

D. (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% chance the customer will use the product, in which case the project will produce after-tax cash inflows of $250,000. Thus, its estimated project cash flows will be $150,000 per year. However, there is a 40% chance that the customer will not use the product, in which case the project will produce after-tax cash inflows of only $75,000. Thus, its estimated project cash flows will be -$25,000. Write out the estimated cash flows and calculate the project's expected NPV under each of the two scenarios.**

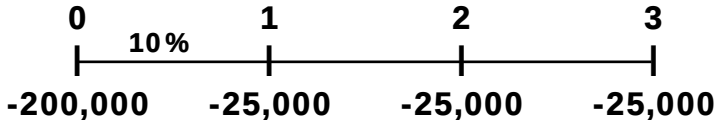
Answer: **[Show S14-11 and S14-12 here.]**

Customer uses product (60% probability)



Using a financial calculator, input the following data: CF_0 = -200000; CF_{1-3} = 150000; I/YR = 10; and then solve for NPV = $173,027.80.

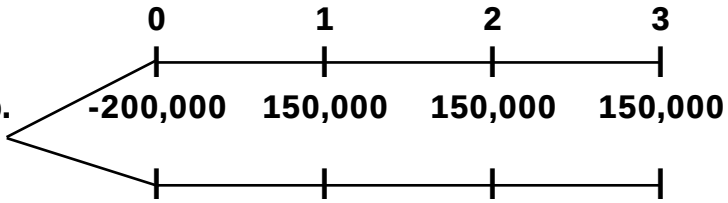
Customer doesn't use product (40% probability)



Using a financial calculator, input the following data: CF_0 = -200000; CF_{1-3} = -25000; I/YR = 10; and then solve for NPV = -$262,171.30.

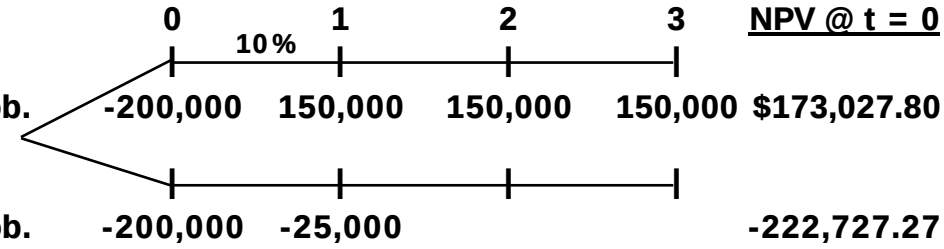
$$E(NPV) = 0.6(\$173,027.80) + 0.4(-\$262,171.30)$$
$$= -\$1,051.84.$$

D. (3) **While 21st Century does not have the option to delay the project, it will know one year from now whether 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 21st Century 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 will be as follows:**



Again, assuming a WACC of 10%, 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?

Answer: **[Show S14-13 and S14-14 here.]**



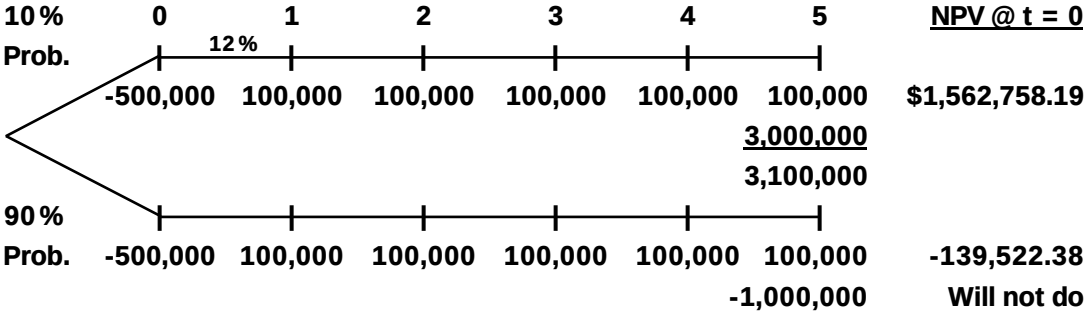
$$E(NPV) = 0.6(\$173,027.80) + 0.4(-\$222,727.27)$$
$$= \$14,725.77.$$

D. (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?**

Answer: **[Show S14-15 here.] It is not reasonable to assume that the abandonment option has no effect on the project's WACC. Having the ability to abandon a project reduces risk; therefore, reducing its WACC.**

E. **Finally, 21st Century is also considering Project Z. Project Z has an up-front cost of $500,000, and it is expected to produce cash flows of $100,000 at the end of each of the next five years (t = 1, 2, 3, 4, and 5). Because Project Z has a WACC of 12%, 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% chance that this will lead to subsequent opportunities that have an expected net present value at t = 5 equal to $3,000,000. At the same time, there is a 90% chance that the subsequent opportunities will have an expected 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? Explain your answer.**

Answer: **[Show S14-16 through S14-19 here.]**



If it turns out that the project at Year 5 has a negative NPV of future opportunities, the firm will not pursue them. Therefore, the cash flows for that branch of the decision tree include only the $500,000 outlay and the $100,000 inflows. Therefore, the expected NPV of Project Z is (0.10)($1,562,758.19) + (0.9)(-$139,522.38) = $30,705.68. Therefore, Project Z has a positive NPV so the firm should invest in it today.