2 Project Initiation and Selection

Learning Objectives

On completion of this chapter, the reader should be able to do the following:

LO 2.1 State why new projects should relate to strategic and operational goals.

LO 2.2 Explain how numeric measures can be used to evaluate proposed risky projects.

LO 2.3 Describe how risk-adjusted discount rates can be used to reflect changing levels of risk throughout a project's life.

LO 2.4 Explain how to apply options thinking to the design and selection of proposed projects.

LO 2.5 Describe the role and importance of stage gates.

LO 2.6 Explain how qualitative measures can be included when evaluating potential new projects.

LO 2.7 Define the role of project portfolios and the relationship between project selection and project portfolios.

2.1 Introduction

Project initiation and selection are the first phase in the project life cycle and the focus of this chapter. Selecting and designing a new project are arguably the most important decisions faced by most organizations. Organizations only succeed in the long run by "doing projects right, and doing the right projects."[1] New projects should be consistent with the overall goals and strategy of an organization (including tolerance for risk). Furthermore, new projects should be viewed as part of an organization's portfolio in the same way that we view any new investment in our financial portfolios. Viewing new projects in this way, we must be concerned about portfolio diversification, cash flows, and resource constraints. Managers must also view the dynamic evolution of project portfolios; as external factors change (including environmental and competitive conditions), organizations should modify their project portfolios appropriately by adding new projects, canceling existing projects, or increasing or decreasing resources assigned to existing or proposed projects.

Following an overview of the project selection process, we present several numerical measures frequently used to evaluate projects' economic viability. These measures include payback period, net present value (NPV)/discounted cash flow (DCF), internal rate of return (IRR), accounting rate of return (ARR), and profitability index (PI). All these measures depend on accurate forecasts of future cash flows; as the accuracy of these forecasts is reduced, so is the usefulness of these metrics.

Following a discussion of simple numerical measures, we discuss more advanced metrics. These measures, including expected NPV and expected commercial value (ECV), more accurately depict projects as a series of stages where decisions are made sequentially over multiple time periods and the probabilities of various outcomes can be included in the selection and design process. We show how this process can be represented and analyzed by decision trees. In addition, we discuss the concept of adjusting discount rates during the life of a project to reflect changing levels of risk at each project stage. Finally, we discuss the concept of "options thinking" and show how this concept can be incorporated into the project selection process to reduce project risk and increase the expected project returns.

To consider nonquantifiable factors, we will discuss scoring and ranking methods where stakeholders can rate each proposed project based on a series of questions. Typically, these questions address factors that are difficult to quantify; for example, "What impact will this proposed project have on the organization's carbon footprint or the organization's sustainability?"

Using the scores from ranking models to evaluate each project proposal, we will show how these scores can be incorporated into a portfolio selection model to determine the selection and timing of proposed projects. This model includes resource constraints and cash flows that must be considered as part of the project selection process to ensure an organization's long-term financial feasibility and viability.

2.2 The Relationship of Projects to Strategic and Operational Goals

LO 2.1 State why new projects should relate to strategic and operational goals.

We can characterize projects in several ways. One classification differentiates projects as strategic or utility projects. **Strategic projects** support the long-term viability of an organization and its stated mission. Most new product development (NPD) and research and development (R&D) projects are strategic projects; these types of projects are typically high-risk projects with uncertain payoffs but are critical to the long-term survival of the organization. **Utility projects**, on the other hand, are generally low-risk projects that improve the effectiveness and/or efficiency of an organization but do not affect the strategic goals of the organization. Most process improvement projects that upgrade current operations are viewed as utility projects. Utility projects are often initiated in response to environmental changes; for example, a manufacturing firm may need to upgrade their facilities to respond to an increasing threat of flooding resulting from global climate change. In general, organizations should strive to maintain a diversified mixture of strategic and utility projects.

Strategic project A type of project supporting the long-term viability of an organization and its stated mission.

Utility project A type of project with low risk serving to improve the effectiveness and/or efficiency of an organization without affecting the strategic goals of the organization.

2.2.1 Initiating Project Proposals

Projects can be initiated in a top-down (e.g., the boss wants it) or bottom-up (e.g., workers see the need) fashion. A bottom-up process might use social media or other Internet-based tools to encourage workers or customers to propose or evaluate new projects or services. In one telecommunications company, senior managers use social networking tools and efficient market theory to encourage employees to develop new project proposals and evaluate other employees' proposals.

Top-down proposals come from senior managers who are reacting to outside market forces or the actions of rival firms but are generally based on an organization's strategic plan. Changes in an organization's mission and vision will trigger adoption of new projects and modification of existing projects. For example, an organization may want to consider new projects that respond to changes in sustainability and environmental goals. Using new technologies, managers are reacting quicker to changes in outside market forces, regulations and laws, and the actions of rival firms. For example, when a rival firm introduces a new or significantly improved product, a firm can respond in numerous ways depending on the trade-offs between market entry time, project development costs, and perceived market demand.

Social networking tools are being increasingly used to tap into existing and potential customer groups to define NPD projects. This approach is based on a "crowdsourcing" theory advocated by Surowiecki and others that large numbers of relatively uninformed people can offer valuable insights and produce promising proposals given that the group exhibits four characteristics:[2]

1. A diversity of opinion
2. Independence (no one can influence others' decisions)
3. Decentralization (many different inputs into process)
4. An effective aggregation mechanism

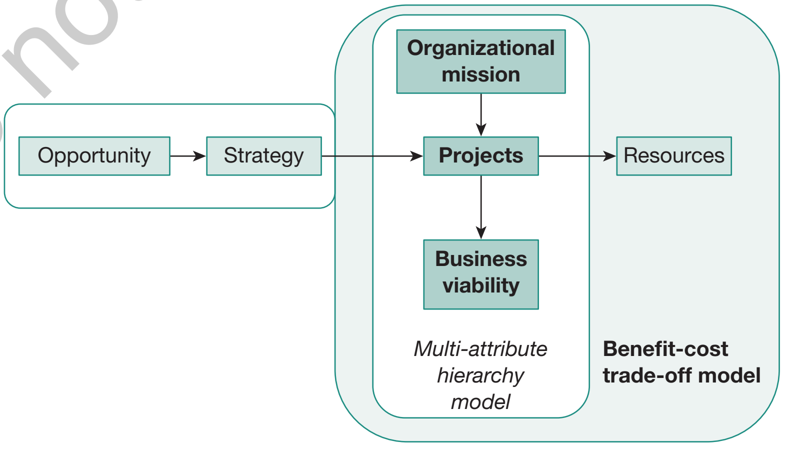
In the absence of these characteristics, however, Surowiecki warns that bubbles and other problems can occur, which may result in the suggestion of poor project proposals.

PM IN ACTION

MONTEREY BAY AQUARIUM

An approach used by the Monterey Bay Aquarium[3] illustrates an effective way to evaluate and select new projects. Their approach was primarily based on two criteria: (1) how well the proposed project contributes to the organization's overall strategy/mission and (2) whether the proposed project contributes to the business viability of the organization. The first criterion was analyzed using a multi-attribute model (i.e., a ranking/scoring method), which measured how well the proposed project supported the mission of the aquarium. Many social factors were included in this model; for example, the extent to which the proposed project supports the ecological and environmental goals of the aquarium. The business viability of any proposed project was analyzed by calculating its expected NPV using cost estimates in four categories (facilities, equipment, personnel, and operations and maintenance) over a 5-year time horizon. Selected projects were expected to meet both the criteria. These metrics are discussed later in this chapter; a conceptual diagram of the selection methodology used by the Monterey Bay Aquarium is given in Exhibit 2.1.

Exhibit 2.1 **Project Selection Methodology at the Monterey Bay Aquarium**



2.3 Simple Numerical Measures

LO 2.2 Explain how numeric measures can be used to evaluate proposed risky projects.

Numerical measures are an important part of the evaluation process of any proposed project. While these measures are criticized (e.g., they are based on forecasted values that are subject to great uncertainty), they provide a good understanding of the explicit costs and benefits of any proposed project. Most organizations use some of these measures in conjunction with other approaches to evaluate new project proposals.

In general, a proposed project should be evaluated on the basis of its marginal increase in costs and benefits resulting from implementing the proposed project (i.e., marginal changes in cash flows). In the following section, we describe several popular numerical measures as well as their merits and limitations.

2.3.1 Payback Period

The **payback period** is defined as the number of time periods (e.g., years) needed to recover the cost of the project.

In general, the payback period is calculated as

Payback period The number of time periods (e.g., years) needed to recover the cost of the project.

$$\text{Payback period (years)} = \frac{\text{Estimated project cost}}{\text{Annual savings (or increase in revenues)}}.$$

EXAMPLE 2.1

CALCULATING PAYBACK PERIOD FOR NEW ATM

Assume a bank can install a new ATM at a cost of $90,000. As a result of this new ATM, the bank can reduce its number of bank tellers by one. Assuming the bank tellers are paid approximately $30,000 per year, the payback period is defined as $90,000/$30,000 = 3 years; that is, it will take 3 years before the bank can recover the initial cost of the ATM installation.

We can extend this measure by considering other changes in cash flows generated by this proposed project. For example, let's assume that the operating costs of the ATM are estimated at $4,000 per year. The annual savings realized in the bank example then becomes $30,000 – $4,000 = $26,000, which results in a payback period approximately equal to 3.5 years ($90,000/$26,000). Similarly, other costs and benefits can be included in the payback period calculation; note, however, that only the marginal changes in cash flows resulting from the proposed ATM are included in the calculation.

The payback period measure is easy to implement and understand but has been criticized for several reasons. Perhaps most important, the metric ignores the time value of money. In the ATM example, we incur the cost ($90,000) of installing the ATM immediately but only realize the savings over a multiyear period. If we believe that the $26,000 saved in the third year is less valuable than the $26,000 saved in the first year (due to inflation and interest rates), this is not reflected in the payback period calculations.

Despite these limitations, payback period remains a popular measure because it is relatively easy to calculate and explain, and may be useful for an organization that is concerned with

EXAMPLE 2.2

USING A PAYBACK PERIOD RULE TO SCREEN NEW PROJECTS

The payback period is sometimes used to define a filter for new project proposals; for example, an organization may specify that only projects with a payback period of *3 years* or less will be considered. (Such rules are sometimes used when economic conditions are uncertain.) For example, consider the case when an organization is trying to decide whether or not to undertake either (or both) Project A or Project B.

Project A: Initial cost = \$75,000; Return = \$25,000 for the following 4 years

Project B: Initial cost = \$120,000; Return = \$20,000 for the first 2 years; \$45,000 for the next 3 years

The payback period for Project A is \$75,000/\$25,000 = 3 years, so it would be acceptable under a 3-year payback rule (earning a net return of \$100,000 – \$75,000 = \$25,000 over the 4-year life of the project). On the other hand, the payback period for Project B would be 4 years and would thereby not qualify for consideration under the 3-year rule. Project B, however, would ultimately return a net gain of \$55,000 over the 5-year life of the project that the organization would lose by using a 3-year payback rule to restrict project selection.

short-run cash flows and profitability. Like all metrics, it should be used with caution and an understanding of its limitations and assumptions.

2.3.2 Net Present Value

Net present value (NPV) The sum of the discounted cash flows (DCFs) over the estimated life of the project.

The **net present value (NPV)** is defined as the sum of the discounted cash flows (DCFs) over the estimated life of the project.

NPV is the most widely used measure for evaluating proposed projects; it recognizes the time value of money (e.g., a Euro today is worth more than a Euro tomorrow) and focuses on the marginal cash flows that are associated with a proposed project. Given an interest or discount rate (also known as the hurdle rate or cutoff rate), we can calculate the discounted stream of future costs and benefits. Let r denote the annual discount rate and F_t denote the forecasted marginal cash flow in year t (i.e., F_t represents the estimated benefits minus the costs associated with the project in year t), the NPV of a project is defined as

$$\text{NPV} = F_0 + \sum_{t=1}^{T} \frac{F_t}{(1+r)^t},$$

where T denotes the estimated life of the project and F_0 denotes an initial investment. This formula assumes all cash flows occur in a single payment at the end of the year; this definition of NPV is known as "discrete discounting."* (We are using years in our calculations here but we could easily be using months, weeks, or any other time period. The discount rate, r, however, would have to be adjusted for the time period used.)

The NPV formula is derived from the equation for simple compound interest. For example, say you have \$4 you can invest at r% (annually). At the end of the first year, you would have an

*If we assume that cash flows occur continuously throughout a time period, $\text{NPV} = F_0 + \sum_{t=1}^{T} F_t e^{-rt}$, where "e" is defined such that the natural logarithm of "e" is equal to 1 (approximately 2.71), and r is the discount rate.

amount equal to \$4(1 + r). At the end of 2 years, you would have an amount equal to \$4(1 + r)(1 + r) = \$4(1 + r)^2 by investing the amount \$4(1 + r) for the second year. At the end of 3 years, you would have an amount equal to $\$4(1+r)^3 = \text{Future value}$, where "Future value" denotes the value of the \$4 investment at the end of 3 years. Since \$4 is the present value of your investment, we know that

$$\text{Present value} = \$4 = \frac{\text{Future value}}{(1+r)^3}.$$

Extending this formula to a multiyear project, let's assume the annual discount rate, r, is 20%. If we expect to incur a cost or negative cash flow of \$750 at the end of the first year, then the associated DCF is*

$$\frac{F_1}{(1+r)^1} = \frac{-\$750}{1.20} = -\$625.$$

If the expected life of this project is 6 years, we can calculate the DCFs for each year in a spreadsheet, given the forecasted revenues (or benefits) and costs as illustrated by the example in Exhibit 2.2. The cash flow F_0 represents an initial investment and is not discounted. Note the net cash flows (i.e., revenues − costs) of this proposed project are not positive until Year 2 when the project starts to generate revenues and the costs associated with the project have decreased to \$550. Summing the discounted net cash flows in the last column, we find the NPV for this proposed project is equal to \$3,204.87. Since the NPV is positive, this project would warrant further consideration. NPV can be calculated directly in an Excel spreadsheet using the *NPV* function.

Exhibit 2.2 Net Present Value Example (6-Year Cash Flow)

Year	Revenues	Costs	Net Cash Flow (Revenues – Costs)	Discounted Net Cash Flows
0	\$0	\$1,000	(\$1,000.00)	(\$1,000.00)
1	\$0	\$750	(\$750.00)	(\$625.00)
2	\$1,500	\$550	\$950.00	\$659.72
3	\$2,000	\$250	\$1,750.00	\$1,012.73
4	\$2,500	\$150	\$2,350.00	\$1,133.29
5	\$2,750	\$130	\$2,620.00	\$1,052.92
6	\$3,000	\$100	\$2,900.00	\$971.20

NPV calculations can be modified to include inflation rates if appropriate. **Inflation** is defined as an overall increase in the price of goods and services without any increase in quality or functionality such that the value of currency is reduced over time. If the forecasted cash flows have not been adjusted for inflation, these "real" cash flows should be adjusted before calculating NPV.

To illustrate, let's assume in the above example that the net cash flows have not been adjusted for inflation and we are expecting an average annual inflation rate of 3% over the expected life of the project. For example, the expected positive cash flow of \$2,350 in Year 4

Inflation An increase in the price of goods and services without any corresponding increase in quality or functionality.

*If we used continuous discounting, the present value for the first year's costs would be $(-750)/e^{-0.2} = -\$614$, where FV = future value = −\$750.

would be worth less than this amount given that some of this gain simply reflects an increase in prices. To adjust cash flows for inflation, we initially use the inflation rate to discount cash flows. If r_{inf} denotes the inflation rate (e.g., r_{inf} 3 = 0.03), the cash flow adjusted for inflation at the end of Year 4 would be

$$\text{Inflation adjusted cash flow at the end of Year 4} = \frac{\$2{,}350}{\left(1+r_{\text{inf}}\right)^4} = \frac{\$2{,}350}{(1.03)^4} = \$2{,}087.94.$$

Assuming a 3% annual inflation rate, we first calculate the inflation-adjusted cash flows indicated in Exhibit 2.3. If we want a real discount rate of 20% (after adjusting for inflation), we discount the inflation-adjusted cash flows using the discount rate, $r = 20\%$. In this case, the NPV is reduced to $2,670.39, reflecting the impact of a 3% inflation rate and a 20% discount rate.

Exhibit 2.3 Net Present Value Example With Inflation Adjustment

Year	Revenues	Costs	Real Cash Flows (Revenues – Costs)	Inflation-Adjusted Cash Flows	Discounted Cash Flows (After Inflation Adjustment)
0	$0	$1,000	($1,000.00)	($1,000.00)	($1,000.00)
1	$0	$750	($750.00)	($728.16)	($606.80)
2	$1,500	$550	$950.00	$895.47	$621.85
3	$2,000	$250	$1,750.00	$1,601.50	$926.79
4	$2,500	$150	$2,350.00	$2,087.94	$1,006.92
5	$2,750	$130	$2,620.00	$2,260.04	$908.26
6	$3,000	$100	$2,900.00	$2,428.70	$813.37

NPV calculations that include inflation adjustments can be done in a single step. In this case, we know the real discount rate $r = 0.20$ and the inflation rate $r_{inf} = 0.03$ and want to find the nominal discount rate r_N to use directly in our calculations. We know that

$$(1+r)(1+r_{\text{inf}}) = (1+r_N)$$
$$1+r+r_{\text{inf}}+r(r_{\text{inf}}) = r_N+1$$

and, therefore,

$$r_N = r + r_{\text{inf}} + r(r_{\text{inf}}).$$

Since $r = 0.20$ (the "real" discount rate) and $r_{inf} = 0.03$ (the annual inflation rate), the nominal discount rate for our example is $r_N = 0.236$. If we take the original real cash flows and discount them directly using the nominal discount rate of 0.236, we get the same discounted net cash flows (after inflation adjustments) indicated in Exhibit 2.3.

While NPV is conceptually better than the payback period measure since it recognizes the time value of resources, it remains subject to criticisms.[4,5,6] First, simple NPV calculations assume that the forecasted cash flows are known with certainty. A related problem is caused by the human bias that is part of the estimation process (or, as one manager stated, "What numbers do you want to see?"). Second, it ignores interactions with other projects and programs in the organization since it treats each project individually. This is an important point; NPV calculations may not capture all costs and benefits when an organization is considering a portfolio of projects that share resources. For example, a project with the small positive NPV that uses slack resources might be more attractive than a project with a larger NPV that requires new facilities or increased overhead costs. For this reason, it is important to focus on marginal cash flows when calculating NPV for any proposed project.

NPV is arguably the best simple numerical measure and should be part of all projects' evaluation process. While an organization might undertake a project with a low or negative NPV (e.g., to counter a competitor or institute a new strategic direction), it is important to assess (as accurately as possible) the sum of the discounted marginal costs and benefits of all proposed projects.

2.3.3 Internal Rate of Return

The **internal rate of return (IRR)** is defined as the discount rate that results in an NPV equal to zero.

Internal rate of return (IRR) The discount rate that results in an NPV (net present value) equal to zero.

Given the uncertainty associated with estimating a discount rate, the IRR finds the value of r (the discount rate) that results in an NPV equal to zero. Generally, those projects with a larger IRR are ranked higher than those with a lower IRR. In addition, the IRR is usually compared with the cost of capital for an organization; under most conditions, a project should promise a higher return than the organization has to pay for the capital needed to fund the project.

To illustrate the calculation of IRR, assume that a project is expected to take 2 years (i.e., $T = 2$). Given the initial investment, F_0, and forecasted cash flows at the end of Years 1 and 2 (F_1 and F_2), you would solve the quadratic equation below to find the IRR:

$$F_0 + \frac{F_1}{(1+r)} + \frac{F_2}{(1+r)^2} = 0.$$

Since IRR assumes that forecasted cash flows are reasonably accurate, it is subject to the same estimation bias that plagues forecasts needed to compute NPV. An additional problem with IRR is the multiple possible positive values of r resulting in NPV = 0; when this occurs, it

EXAMPLE 2.3

CALCULATING INTERNAL RATE OF RETURN

Assume that a proposed project will require an initial outlay of \$100 but will return \$40 (benefits – costs) at the end of the first year and \$75 in net benefits at the end of the second year. To find the IRR, we must then solve the following quadratic equation for r:

$$-100 + \frac{40}{(1+r)} + \frac{75}{(1+r)^2} = 0,$$

which can be simplified to

$$r^2 + 1.6r - 0.15 = 0.$$

Solving this quadratic equation,* we find that r can equal either 0.089 or –1.689 (both values set NPV equal to zero). In this case, we ignore the negative value of r and assume the value of IRR as 8.9%.

*Using the quadratic formula or other appropriate method.

is unclear how these multiple values should be interpreted or which value of r should be adopted. However, when a project has a series of negative cash flows followed by (only) positive cash flows, there is only a single positive value of r that satisfies the equation NPV = 0. In such a case, IRR is comparable with NPV and may be used interchangeably.

2.3.4 Accounting Rate of Return

Accounting rate of return (ARR) A financial metric used to evaluate potential projects based on the average annual return, depreciation, and initial investment.

The **accounting rate of return (ARR)** is defined as the return on investment defined by average earnings divided by average initial investment.

ARR is a simple ratio of average estimated earnings divided by the initial investment, where earnings are adjusted for annual depreciation. Specifically, it is expressed as

$$\text{ARR} = \frac{\text{Annual cash inflow} - \text{Annual depreciation}}{\text{Initial investment}}.$$

EXAMPLE 2.4

CALCULATING ACCOUNTING RATE OF RETURN

Assume you can purchase a new machine for \$18,000 that will return a savings of approximately \$4,200 per year for an expected 8-year period. At the end of this 8-year period, you can sell the machine for \$1,200 (salvage value).

Using straight-line depreciation, the annual depreciation would be

$$\text{Annual depreciation} = \frac{\$18{,}000 - \$1{,}200}{8 \text{ years}} = \frac{\$16{,}800}{8 \text{ years}} = \$2{,}100.$$

Thus, the ARR is defined as follows:

$$\text{ARR} = \frac{\$4{,}200 - \$2{,}100}{\$18{,}000} = 11.67\%.$$

The ARR has been criticized on numerous dimensions. Similar to the payback period, it ignores the time value of money. However, unlike the payback period (which places a limit on a project's payback time and is therefore viewed as a conservative rule), ARR places no such limits and can be quite risky since cash flows are not discounted. For example, assume a proposed project is forecast to return several billion dollars in 10,000 years in the future. Because there are no discounting or time constraints, the ARR metric might cause this project to appear very favorable even though such forecasts are basically nonsense.

The ARR also includes non–cash flows (i.e., depreciation). Since non–cash flows do not affect an organization's long-term revenues and profits (except for a possible impact on taxes), non–cash flows should be ignored when evaluating a project's potential value. For these reasons, ARR is a good metric to avoid.

2.3.5 Profitability Index

The **profitability index (PI)** is defined as the ratio of discounted future returns divided by the initial investment.

Profitability index (PI) The ratio of discounted future returns divided by the initial investment.

The PI is defined as follows:

$$PI = \frac{\text{Present value of future cash flows}}{\text{Initial investment}}.$$

If the value of the PI is greater than some predefined threshold, the project would be accepted; if it is below the threshold, the project would be rejected. Typically, the threshold is equal to one (i.e., the present value of the future cash flows equal or exceed the initial investment).

The PI is similar to a discounted benefit–cost ratio used by many organizations. The PI is frequently used for ranking multiple proposed projects. The PI, however, has a serious limitation as illustrated in the following example.

EXAMPLE 2.5

CALCULATING PROFITABILITY INDEX

Assume we are comparing two projects that both have positive returns over an expected 4-year life. Given a discount rate of 16%, the cash flows for both projects are indicated in Exhibit 2.4.

Using the DCFs, the PI for Project A is equal to $2,798.18/$2,500 = 1.12, while the PI for Project B is 1.60. However, when computing the NPV, we find that Project A has an expected NPV equal to $298.18, while the NPV for Project B is only $209.64. If we can only select one of these projects, we would select Project B using the PI even though it has almost a 30% lower return than Project A.

Exhibit 2.4 Profitability Index Illustrated

	Year				
	0	1	2	3	4
			Forecasted Cash Flows		
Project A	($2,500)	$1,000	$1,000	$1,000	$1,000
Project B	($350)	$200	$200	$200	$200
			Discounted Cash Flows		
Project A	($2,500)	$862.07	$743.16	$640.66	$552.29
Project B	($350)	$172.41	$148.63	$128.13	$110.46

This example illustrates that the PI is a relative measure (to a project's initial investment), while NPV is an absolute measure. If we cannot perform multiple versions of Project B and only one project can be selected, then NPV and Project A would appear to be the better choice.

2.4 Advanced Measures

LO 2.3 Describe how risk-adjusted discount rates can be used to reflect changing levels of risk throughout a project's life.

The previous definition of NPV has been criticized on the grounds that it assumes forecasted cash flows are known with certainty. The definition of NPV, however, can be extended to include uncertainty. To illustrate, consider a proposed NPD project with two alternative design options, A_1 or A_2. The manager can select either alternative A_1 or A_2. If the manager selects alternative A_1, then three outcomes or states of nature (with values equal to S_1, S_2, or S_3) could result with probabilities (p_1, p_2, or p_3, respectively). The specific state of nature that occurs is an exogenous event that is outside of the manager's control. If the manager selects alternative A_2, three other outcomes or states of nature are possible (S_4, S_5, or S_6) with probabilities (p_4, p_5, or p_6, respectively). This example illustrates a multistage sequential decision-making problem that represents many projects and could be extended to include additional alternatives, outcomes, and so on.

Decision tree A tool that uses a branching structure to map out decision points and consequences, including uncertain events.

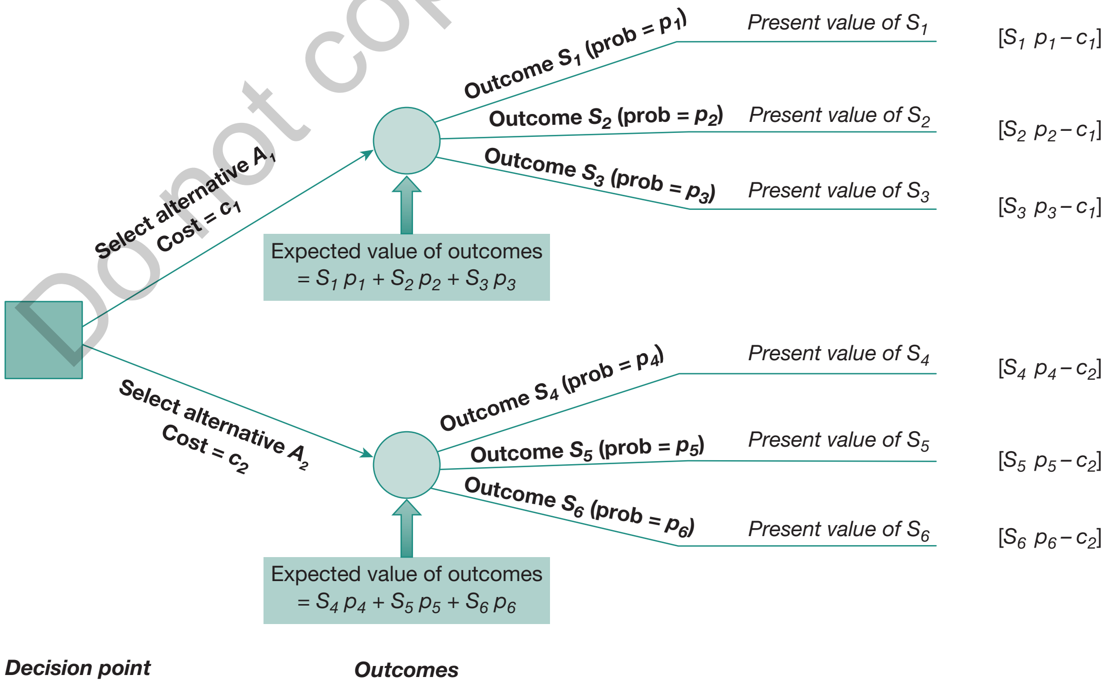
A **decision tree** is a useful device for representing a sequential decision-making problem; the decision tree in Exhibit 2.5 represents the generic project described above. As indicated in this decision tree, we initially must choose alternative A_1 or A_2. If we select alternative A_1, the expected outcome* is $(S_1)(p_1) + (S_2)(p_2) + (S_3)(p_3)$. If we select alternative A_2, the expected outcome is $(S_4)(p_4) + (S_5)(p_5) + (S_6)(p_6)$. Working backward, we can then find the expected payoff for each alternative by subtracting the cost of each alternative from its respective expected outcome. If c_i denotes the cost of alternative i ($i = 1, 2$), then the expected value of each alternative is

$$\textit{Expected value of Alternative } A_1\text{: } (S_1)(p_1) + (S_2)(p_2) + (S_3)(p_3) - c_1,$$

$$\textit{Expected value of Alternative } A_2\text{: } (S_4)(p_4) + (S_5)(p_5) + (S_6)(p_6) - c_2.$$

Typically, the outcome values, S_i, represent the DCFs resulting from each alternative and its resultant outcome or state of nature. The expected NPV of the project is the value of the alternative with the largest expected value.

Exhibit 2.5 Decision Tree Example



*Remembering that the **expected net present value** is the sum of the cash flows multiplied by their respective probabilities.

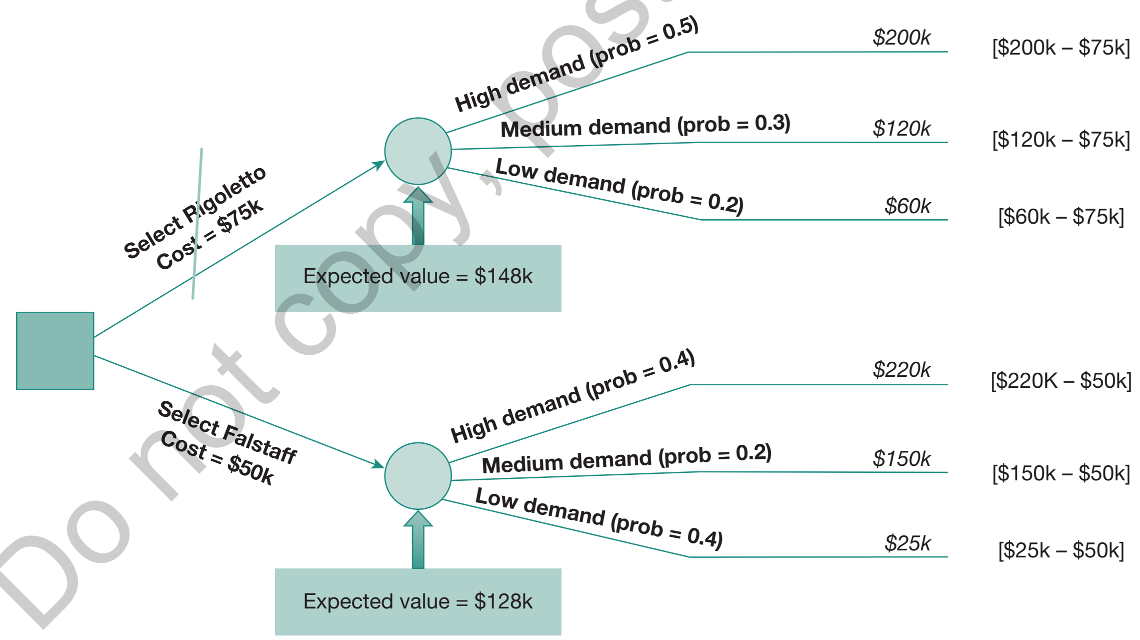
EXAMPLE 2.6

OPERA SELECTION PROBLEM

Consider an opera company that is trying to decide which opera to select for the opening performance of its season. (The company can only select one opera for its opening performance.) For each opera, the company managers have estimated the possible demands (high, medium, low) and their respective revenues and probabilities. Assuming two possible operas (Rigoletto or Falstaff), the decision tree for the opera selection problem faced by the opera company is given in Exhibit 2.6. We assume the revenues and costs represent appropriately discounted present values.

If the opera company selects Rigoletto, the estimated expected revenue would be \$148,000 (= 0.5 × \$200,000 + 0.3 × \$120,000 + 0.2 × \$60,000). If the company selects Falstaff, their expected revenue would be \$128,000 (= 0.4 × \$220,000 + 0.2 × \$150,000 + 0.4 × \$25,000). Assuming that Rigoletto would cost an estimated \$75,000 to perform (cast, set, director, etc.), the opera company would realize an estimated gross profit of \$148,000 – \$75,000 = \$73,000. If they select Falstaff (which we assume would cost approximately \$50,000 to produce), their estimated gross profit would be \$128,000 – \$50,000 = \$78,000. Thus, based on expected gross profit, the opera company could expect to make an additional \$5,000 if they select Falstaff to open their season (although there are still many good reasons why they might select Rigoletto instead).

Exhibit 2.6 **Opera Selection Problem**

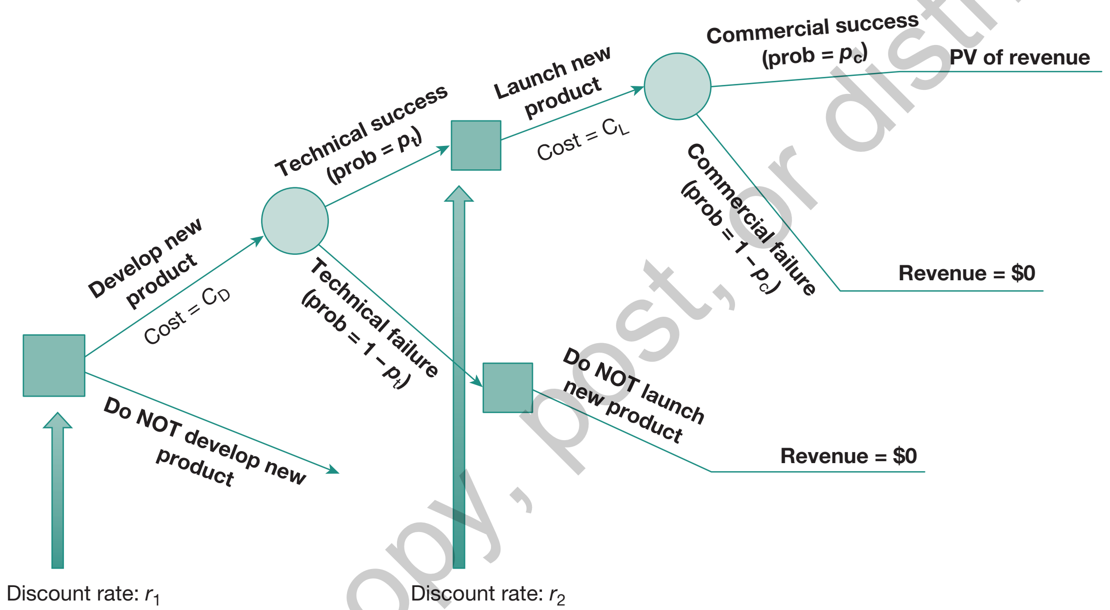


2.4.1 Risk-Adjusted Discount Rates

The expected NPV or E(NPV) in the previous example considers the uncertainties of various outcomes by weighting forecasted revenues by their respective probabilities. However, our calculation of E(NPV) was based on a single hurdle rate to discount all cash flows throughout the project. Also, most projects consist of multiple stages (e.g., design, marketing, implementation) that occur sequentially over time. As a project evolves, the corresponding risks associated with each subsequent stage of a project are typically reduced as more information is gained and tasks are completed; this risk reduction should be reflected by corresponding lower discount rates. (If the risk of a project *increases* over time, you should consider terminating this project.)

When we use differential discount rates at various stages of a project, the E(NPV) is sometimes known as the expected commercial value (ECV). To illustrate ECV-type measures, consider the decision tree in Exhibit 2.7 for a hypothetical product development project. As indicated, there are two decision points: (1) to develop (or not develop) the product and (2) to launch (or not launch) the product.* If the product is developed, it could be a technical success (with probability p_t) or technical failure (with probability $1 - p_t$); if it is launched, it could be a commercial success with probability p_c or a commercial failure (with probability $1 - p_c$). In Exhibit 2.7, we assume we do not launch the product if it is a technical failure (so that future cash flows are zero in this case). If the product is a commercial success, we earn a revenue denoted by "PV of Revenue" as shown in Exhibit 2.7.

Exhibit 2.7 Expected Commercial Value (ECV) Measure Illustrated



Note. PV = present value.

Note that we use two different discount rates in this decision tree: one rate (r_1) at the beginning of the project and another rate (r_2) at the decision point to launch (or not) the new product. Since we know that the project is a technical success when deciding to launch, the risk is much lower than at the beginning of the project. Hence, we would expect r_2 to be lower than the discount rate r_1 to reflect this difference.

The decision tree in Exhibit 2.7 could be modified to reflect additional alternatives or outcomes. For example, there could be more than two possible outcomes if the project is launched—launch the product in a few test markets or launch the product overall. Decision trees are useful devices for communicating and analyzing complex sequential decision-making problems that are part of most project evaluation processes.

To illustrate ECV-type measures, consider a proposed NPD project described by Hodder and Riggs.[7] In the first phase, the product will be developed and the technical feasibility explored; it is estimated that this phase will cost $18 million per year and will require 2 years to complete.

*Always remember, to paraphrase the economist Milton Friedman, that there is no such thing as a free launch.

There is a 60% probability that the company can successfully develop the new product. If successful, the second phase will be undertaken to explore the market feasibility of the product and develop marketing and logistics channels. This phase of the product development process will require 2 more years and cost $10 million per year. It is expected that the market research conducted in this phase will indicate sales potential of the new product; the sales potential could be high (with a 30% probability), medium (with a 50% probability), or low (with a 20% probability). If the sales potential is estimated to be low, the product will be dropped, and manufacturing and sales will not be started. The estimated costs and revenues relating to this proposed NPD project are summarized in Exhibit 2.8.

Exhibit 2.8 New Product Development Project Illustrated

Phase I	**Research and Product Development**
	$18 million annual research cost for 2 years; 60% probability of success
Phase II	**Market Development**
	Undertaken only if product development is successful; $10 million annual expenditure for 2 years to develop marketing and distribution channels (net of any revenues earned in test marketing)
Phase III	**Sales**
	Proceeds only if Phases I and II verify opportunity. Production is subcontracted and all cash flows are after tax and occur at year's end. The results of Phase II (available at the end of Year 4) identify the product's market potential as indicated below:

Product Demand	Product Life	Annual Net Cash Inflow	Probability
High	20 years	$24 million	0.3
Medium	10 years	$12 million	0.5
Low	Abandon project	None	0.2

If we calculate an IRR to evaluate this project (based on "standard" DCF), we would generate the table in Exhibit 2.9 with expected cash flows for the 24-year estimated life of the project. In this example, we find that the IRR is 10.12%; that is, we would expect this project to generate an average annual return slightly above 10% over its possible 24-year duration. Depending on the cost of capital and current interest rates, such a project might (or might not) appear attractive.

Exhibit 2.9 Expected Cash Flows for New Product Development Example

Year	Expected Cash Flow (in $ Million)
1	–18
2	–18
3	$0.6(-10) = -6$
4	$0.6(-10) = -6$
5 – 14	$0.6(0.3 \times 24 + 0.5 \times 12) = 7.92$
15 – 24	$0.6(0.3 \times 24) = 4.32$

As mentioned, one criticism of NPV (and IRR) is the use of a single discount rate over the life of a project. Generally, we assume that the risk associated with the beginning of the project is significantly greater than the risk associated with the latter part of the project (as we would expect). Thus, it would seem reasonable to use different discount rates at these stages to reflect this difference in risk. We will extend this concept to the NPD project indicated in Exhibit 2.8.

Specifically, let's assume (following Hodder and Riggs) we do not want to manufacture and market this product if we successfully develop the product and find that there is a viable market (manufacturing and sales are not our core competencies). In this case, we decide to sell the product to a third party (e.g., an original equipment manufacturer, or OEM) who would manufacture and sell the product. What is the expected value of the product at that point in time?

Since the product has been developed and the market research completed (and successful), there is much less risk associated with the manufacture and sale of this product than at the beginning of the project. Given the reduced risk, let's assume an OEM would be satisfied with a return of 5% for the newly developed product with a viable market. Given a discount rate of 5%, the expected value of the product at the end of Year 4 could be calculated by discounting $24 million per year for 20 years (equal to $299.09 million) and $12 million per year for 10 years (equal to $92.66 million). Since the probability of having a high demand is 0.3 and the probability of having a medium demand is 0.5, the expected value of this product would be equal to 0.5 × $299.09M + 0.3 × $92.66M = $136.06M at the end of Year 4. The expected cash flows for this project are indicated in Exhibit 2.10.

Exhibit 2.10 Cash Flows When Developed Product Is Outsourced

Year	Expense (in $ Million)	Probability	Sales (in $ Million)	Expected Cash Flow (in $ Million)
1	($18)	1		($18.00)
2	($ 8)	1		($18.00)
3	($10)	0.6		($6.00)
4	($10)	0.6	$136.06	$75.64

Note. All values are in $ million.

Using the cash flows in Exhibit 2.10, we now find that the IRR is equal to 28.5%—a value that is almost 3 times as great as the initial IRR we estimated! The difference is based on the use of differential discount rates for different phases of the project; we are no longer assuming that a single discount rate is appropriate for the entire project. By recognizing that the risk is reduced as the project progresses, the project appears to be far more attractive than indicated when we naively used a single discount rate for the entire project life span.

2.5 Implementing "Options Thinking"

LO 2.4 Explain how to apply options thinking to the design and selection of proposed projects.

One of the implications of the previous example is the concept that managers should consider designing new projects with milestones representing times where resource allocation decisions can be reconsidered and/or renegotiated. In the previous NPD example, deciding to proceed with the R&D phase merely gives managers the right (but not the obligation) to proceed with the following market development phase if the R&D phase was successful. The decision points in the previous example's decision tree illustrate the options available to project managers. Building these options into a project plan can increase the expected value of a project significantly as the previous example demonstrates. This flexibility is related to the concept of "Agile project management," where projects are organized into a series of small "mini-projects" called iterations or sprints; at the end of each sprint, the following sprint is organized based on the outcome of the previous sprint. Agile PM has become popular in recent years and is discussed in Chapter 3 Supplement.

The use of multiple decision points where resources can be reconsidered is analogous to purchasing a **real option** in financial investments; a real (call) option is a contract that gives the owner the right (but not the obligation) to purchase a good at a stated price in the future. A European option specifies that the purchase decision can only occur at a specific point in time; an American option specifies that the purchase decision can occur anytime prior to the expiration date of the contract. Logic dictates that the value of an American option is at least as great as the value of a European option. If you exercise the option and purchase the good, the specified price is known as the **strike price**.

Real option A contract giving the owner the right (but not the obligation) to purchase a good at a stated price sometime in the future.

Strike price The specified price of a good in a real option contract.

The value of an option contract can be estimated using the Black–Scholes option pricing model developed by Fischer Black and Myron Scholes in 1973.[8] The model estimates the value of a European option based on the following assumptions:

- It is possible to borrow and lend cash at a known risk-free rate of return that remains constant over the life of the option.
- The value of the good follows a log-normal distribution with a constant standard deviation over the life of the option.
- There are no transaction costs.
- The good is perfectly divisible (i.e., it is possible to purchase a fraction of the good).
- There are no restrictions on short-selling.

Some companies have used the Black–Scholes option pricing model to evaluate proposed projects; however, the application of the option pricing model to new project proposals has two drawbacks. First, the Black–Scholes formula is complex and difficult for most managers to understand. Second, the model is based on assumptions that may be inappropriate for most projects; for example, it assumes that the future values of an asset follow a log-normal distribution. To date, we have no evidence supporting or refuting this assumption for NPD—or other—complex projects.

Nevertheless, it is important for project managers to retain an "options thinking" mindset when designing and implementing new projects; such thinking gives managers greater flexibility to respond to unplanned events. Huchzermeier and Loch showed that such flexibility can significantly increase the expected value of a project—especially for high-risk strategic projects.[9] They identified four basic options that managers can implement at various project milestones:

1. *Defer option*: Delay a project for some time until additional information becomes available.
2. *Abandonment option*: Structure the project so that "go–no go" decisions can be made at each milestone and some benefits will be retained (even if the project is abandoned).
3. *Expansion or contraction option*: Expand or reduce the scale of the project.
4. *Switching option*: Change the mode of project activities (e.g., using more or fewer subcontractors, switching to new raw material suppliers).

2.5.1 Putting Options Thinking Into Practice

Many proposed projects do not require that managers immediately decide whether or not to commit to completing the project; rather, they must decide if they should invest some level of resources into the initial stage of the project. For example, consider a proposal to make a movie based on a recently published book. The first decision faced by the movie studio is to decide whether or not to purchase the film rights for the book; after purchasing the film rights, the movie studio can decide to make the movie. The film rights are equivalent to a real option; they give a movie studio the right (but not the obligation) to make a movie based on the book.

EXAMPLE 2.7

BUYING MOVIE RIGHTS FOR A BOOK

To illustrate this process further, consider the case of a movie studio that is considering purchasing the film rights to a recent best-selling book for $2 million. The movie studio has done some preliminary analysis that indicates the domestic U.S. market for this movie could be favorable with a probability of 0.2. (To reduce the complexity of this example, we will restrict ourselves to only considering the domestic U.S. market.) If the market is favorable, the movie studio estimates the discounted domestic U.S. revenues for this movie could be high, average, or low as indicated in Exhibit 2.11. As indicated, the expected domestic U.S. revenues for a favorable market would equal $136.25 million.

Exhibit 2.11 Cash Flows When Market Is Favorable

Demand Forecast	Domestic Gross Sales ($ Million)	Probability	E(Sales) $ Million
High	$195	0.25	$48.75
Average	$170	0.35	$59.50
Low	$70	0.4	$28.00
			$136.25

If the domestic U.S. market is unfavorable (which the movie studio thinks may occur with probability 0.8), the discounted revenues are given in Exhibit 2.12. In this case, the expected revenues are reduced to $85.50 million.

If the movie studio commits to making this movie (at an expected cost of $100 million), the expected NPV for this project would be calculated as follows (all calculations are in $ millions and are appropriately discounted):

Exhibit 2.12 Forecast Cash Flows When Market Is Unfavorable

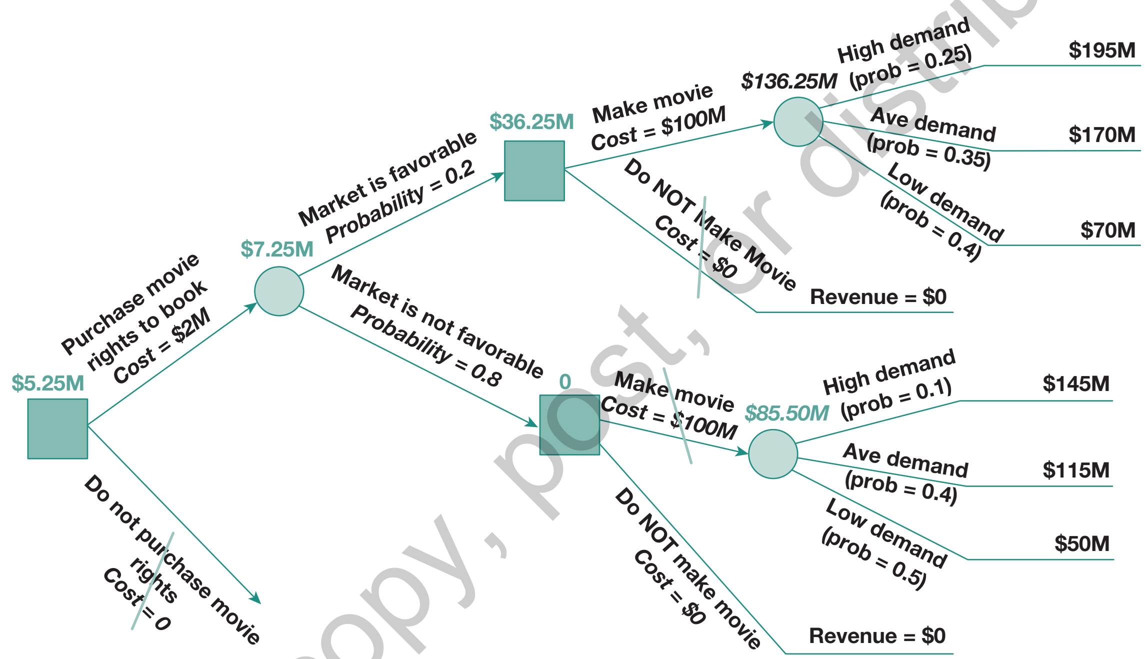
Demand Forecast	Domestic Gross Sales ($ Million)	Probability	E(Sales) $ Million
High	$145	0.1	$14.50
Average	$115	0.4	$46.00
Low	$50	0.5	$25.00
			$85.50

E(NPV) = 0.2 × $136.25M + 0.8 × $85.50M − $2M − $100M = −$6.35M.

Given an expected loss of $6.35 million, the movie studio would be unlikely to pursue this movie project.

However, let's say the movie studio decides to implement a flexible strategy based on "options thinking." Specifically, they only consider the decision to purchase (or not) the film rights for the book (at a cost of $2 million) at the present time and decide to postpone the decision to make (or not) the movie to a later date when they can better understand the likely market outcomes before deciding whether or not to make the movie. The movie studio's decision process can be represented by the decision tree indicated in Exhibit 2.13. Following previous practice, decisions faced by the movie studio are represented by the rectangles while states of nature (i.e., outcomes randomly determined by the market or other external forces) occur at the circles in the diagram.

Exhibit 2.13 **Movie Project Decision Tree**



Note. Ave = average; prob = probability.

If the market is favorable, the expected profit from making the movie is 0.2 × ($136.25M − $100M) = $7.25M as indicated in Exhibit 2.13. If the market is unfavorable, however, the movie studio knows that if they make the movie they would incur an expected loss of ($85.50M − $100M =) $14.50M, so they would choose to not make the movie in this case. Clearly, the studio's expected revenue would be $0 if they do not make the movie.

To summarize, the movie studio would make the movie if market conditions are favorable and not make the movie if market conditions are unfavorable (after purchasing the movie rights for $2 million). In this case, the movie studio would have an expected profit of $7.25M − $2M = $5.25M using an "options thinking" approach. The difference between the expected profit using an options approach ($5.25 million) and the expected loss using a simple NPV calculation (−$6.35 million) is $11.60 million; this value is called the "option value" and represents the expected gain that the movie studio would realize by implementing a flexible approach based on "options thinking."

2.5.2 Project Timing: The Defer Option

The second example illustrates how the "defer option" described by Huchzermeier and Loch may increase the expected value of a proposed project.[10] In this example, we consider the timing decision faced by a company that is considering the development of a new drug. Specifically, the company's managers must decide to launch the NPD project now or wait for more information and launch the project in the future (or not at all). Of course, if the managers delay starting the project, they give their competitors additional time to develop a competing drug and delay getting the drug to patients who might need it.

Specifically, the company considering the development of this drug estimates it will take 1 year to develop and manufacture the drug at an expected cost of $12 million. Characteristic of most new drug development projects, company managers will not know if the development effort is successful until the end of the development process. The company thinks the probability that this development effort will be successful is 0.55. If the product development effort is successful, the company estimates they will earn $8.5 million annually for 5 years following the product introduction. If the product development fails, however, the company will earn no revenue.

2.5.2.1 Launching the NPD Project Immediately (in Year 1)

We will assume the company uses an annual discount rate of 14% and all cash flows occur at the end of the year. If the development effort is successful, the 6 years of DCFs (1 year of development and 5 years of sales) are given in Exhibit 2.14; as indicated, the DCFs sum to $15.07 million. If the development effort fails, the company incurs a loss of $10.53 million ($12 million discounted for 1 year at 14%). Thus, the expected NPV for this project, if launched immediately, is equal to $3.55 million (= 0.55 × $15.07M + 0.45 × –$10.53M).

Exhibit 2.14 Estimating Net Present Value When Launching New Product Project Immediately

	Project Successful (0.55)		Project Fails (0.45)	
Year	F_t	Discounted F_t	F_t	Discounted F_t
1	–$12.00	–$10.53	–$12.00	–$10.53
2	$8.50	$6.54	$0	$0
3	$8.50	$5.74	$0	$0
4	$8.50	$5.03	$0	$0
5	$8.50	$4.41	$0	$0
6	$8.50	$3.87	$0	$0
		$15.07		–$10.53

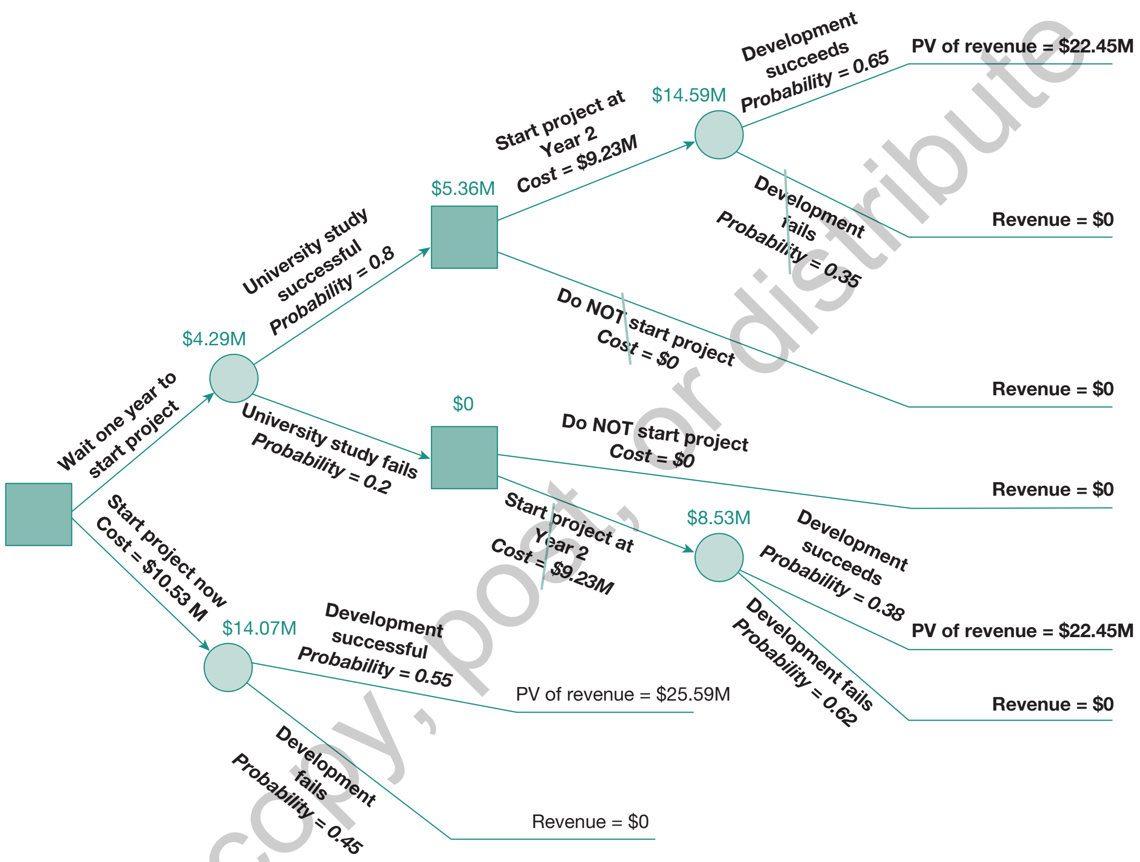
Note. All values are in $ millions.

2.5.2.2 Delay Start of NPD Project Until Year 2

Now, however, assume the company learns that a university research center has been conducting a multiyear study on a similar drug; the results from the university study could provide information about the potential success of the company's drug development project. The results of this university research study will be known in 1 year. Specifically, if the university research study is successful, the probability of the company's drug succeeding in the marketplace increases to 0.65 (although the company would still have to incur the 1-year $12 million development fee). If the university research study fails, however, the probability of the drug development project succeeding is reduced to 0.38. The university researchers estimate that there is a 0.8 probability that the university study will be successful. Should the company begin developing their drug now or should they delay starting the development of their drug for a year until they know the outcome of the university research study?

This problem can be analyzed by the decision tree in Exhibit 2.15. The $22.45 million is the sum of the sales ($8.5 million) in Years 3 to 7 that are discounted back to the beginning of Year 3 at 14%, assuming that the development project is successful. The $14.59 million amount is equal to 0.65 × $22.45M; the $5.36 million is equal to $14.59M – $9.23M ($9.23 million is the discounted $12 million development cost).

Exhibit 2.15 Decision Tree for New Drug Development Project



As indicated in Exhibit 2.15, the expected NPV in the project increases to $4.29 million when the company postpones the launch of their NPD project for a year until it learns the results of the university study. Obviously, other costs and benefits should be included in this decision, including the importance of the drug and the possible reaction of competitors. However, based on the expected NPV, the defer option appears to be the preferred strategy in this case since it results in an NPV increase of $4.29M – $3.55M = $0.74M.

2.6 "Stage Gates" Defined

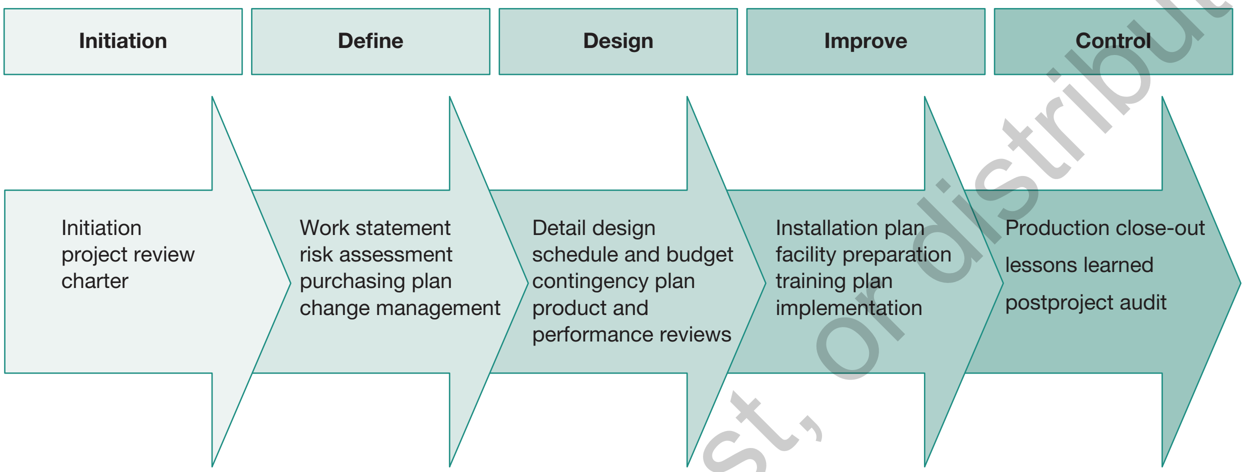
LO 2.5 Describe the role and importance of stage gates.

Stage gate A decision-making approach requiring a project be defined as a series of stages where each stage must pass a review before proceeding to the following stage; also known as tollgate.

A flexible approach based on "options thinking" is related to the use of "**stage gates**" or "tollgates," which are widely used by many organizations. This approach requires a project be defined as a series of stages where each stage must pass a review before proceeding to the following stage. An example of a "stage-gate" approach used by a corporate information technology (IT) division is given in Exhibit 2.16. The importance of these stage gates in helping to complete an IT project successfully was emphasized by Cooper et al.:

> Most companies' development portfolios suffer from: too many projects for the limited resources available; ineffective project prioritization; Go/Kill decisions made in the absence of solid information; and too many minor projects in the portfolio. . . . The first [solution] is to implement a systematic gating or Stage-Gate new product process, complete with tough Go/Kill decision points.[11]

Exhibit 2.16 **Example "Tollgate" Approach for Information Technology Projects**



According to Cooper et al., companies that use a stage-gate approach had a 37.5% higher success rate at launch than companies not using such an approach and a 72% better chance of meeting profit objectives over the life of the product.

A tollgate approach can also help with the decision to terminate a project prematurely (i.e., pull the plug). In many organizations, it may be difficult to cancel an ongoing project when changing environmental conditions or new technologies require project termination (due to a perceived—or real—reduction in merit evaluation, pay, or even jobs). A tollgate approach, with definitive "go–no go" decisions at each gate, can help in this respect.

2.7 Ranking and Scoring Methods

LO 2.6 Explain how qualitative measures can be included when evaluating potential new projects.

While there are many numerical measures used to evaluate project proposals, many of these measures ignore qualitative factors as well as some secondary costs and benefits that may be difficult to quantify directly. To include these factors, some organizations use scoring or ranking models, which typically consist of a list of various attributes and weights associated with these attributes. The choice of attributes, their respective weights, and the method of combining these scores and weights into a single measure is the key to a successful scoring method that can assist managers when evaluating new project proposals.* A list of possible attributes for a proposed NPD project is indicated in Exhibit 2.17.

*In cases, forced ranking of proposal attributes may be used to help alleviate the objection stated by some managers that these models fail to adequately discriminate among project proposals.

Exhibit 2.17 Example Attributes for Ranking/Scoring Method

Example Scoring/Ranking Model

Project Name ____

Organization's Strategy

1. Consistent with organization's mission statement
2. Help to ensure long-term organizational viability
3. Impact on the long-run profitability of organization

Risk and Market Factors

1. Probability of research being successful
2. Probability of development being successful
3. Probability of process success
4. Probability of commercial success
5. Overall risk of project
6. Adequate market demand
7. Impact on competitors in market

Organization Costs

1. Is new facility needed?
2. Can use current personnel?
3. Are external consultants needed?
4. Are new hires needed?

Miscellaneous Factors

1. Impact on environmental standards
2. Impact on workforce safety
3. Impact on quality
4. Social/political implications

When using these methods, we should adjust the scores if some of the attributes are correlated; for example, we might expect that market share (a "value" measure) and potential market demand (a "risk" measure) would be positively correlated. Correlated attributes have the effect of implicitly increasing the weight associated with the underlying factor(s). For the example in Exhibit 2.17, it appears that at least four of the attributes are related to market demand for the new product. Thus, market demand might be the driving factor in determining the overall score for this proposed project. To eliminate these implicit weights, we can use a statistical methodology such as principal components (or factor) analysis to identify the natural or underlying "factors" in the data. Once identified, these orthogonal factors can be used to calculate an overall score for each proposed project.

For any ranking/scoring method, there are a number of ways to quantify the listed attributes. For example, each attribute can be rated on a Likert-type scale (e.g., from 1 to 10), evaluated on a "yes" or "no" basis or ranked in comparison with other attributes (i.e., a forced ranking).

The wording of each attribute must be carefully stated to reflect the fact that a higher score represents a greater value (or vice versa, as long as there is consistency). For example, a "yes" to the question asking if the project will increase profitability is certainly positive (and should increase the project score), whereas a "yes" to the question asking if a new facility is needed may be viewed as negative (and should lead to a lower project score).

When attributes are evaluated on different measurement scales, all responses should be transformed to a common scale. For example, assume that some attributes are scored on a Likert-type scale between 1 and 7, where a higher score is viewed as more positive. To convert these scores to a (0, 1) scale, we can use a linear transformation where U denotes the upper bound of the scale ($U = 7$) and L denotes the lower bound ($L = 1$). Given a score x_i (where $1 \le x_i \le 7$), the transformed score of this attribute $v_i(x_i)$ can be calculated using the formula

$$v_i(x_i) = \frac{x_i - L}{U - L}.$$

For example, if $x_i = 3$, the transformed value $v_i(x_i) = (3 - 1)/(7 - 1) = 2/6 = 0.33$. Similarly, a value of $x_i = 1$ will result in a transformed value of 0 (as expected), and a score of $x_i = 7$ will result in a transformed value of 1.

If the response to an attribute is limited to three choices (e.g., demand might be low, medium, or high), we can assume that a "low" score is equivalent to 0, a "medium" score is equivalent to 1, and a "high" score is equivalent to 2. The values $v_i(x_i)$ will then be transformed to 0, 0.5, and 1, respectively, for "low," "medium," and "high" since $L = 0$ and $U = 2$.

We note that many other transformations can be used, including quadratic and exponential transformations. It is important to remember, however, that these calculations can influence a project's score and perceived desirability, so care should be taken when calculating and interpreting these results.

Using the transformed values $v_i(x_i)$ for each ith question or attribute, we can compute an overall score V_j for each jth project proposal using the $v_i(x_i)$ values. To compute an overall score, we assign a nonnegative weight w_i to each ith attribute, which reflects the relative importance of each attribute. Generally, we require these weights satisfy the constraints

$$0 \le w_i \le 1 \text{ and } \sum_i w_i = 1.$$

Given attribute scores and weights, we can calculate an overall score V_j; using an additive model, the overall project score V_j is defined as

$$V_j = \sum_i w_i \, v_i(x_i).$$

EXAMPLE 2.8

RANKING AND SCORING METHODS ILLUSTRATED

To illustrate how we can use this approach to develop a score for each proposed project, consider the example in Exhibit 2.18, which presents five attributes and their associated weights (w_i); these attributes include an assessment of the likelihood that the project will increase market share, whether or not a new facility is needed, and so on. For the first, fourth, and fifth attributes, we rated these on a 5-point scale. In the case of the second attribute ("Is a new facility needed?"), a "yes" response was scored as a "2" on our 5-point scale, while a "no" response was scored as a "4" (note that this is arbitrary; we could have scored a "yes" as a "1" and a "no" as a "5").

In similar fashion, the third attribute ("Are there safety concerns?") is scored so that a response of "likely" was given a value of "1," while an assessment that we are "unsure" received a value of "3," and an assessment that safety is not an issue received a score of "5." In this way, higher values on all five attributes contribute to a more favorable rating of the associated project.

Assume we are considering two projects, A and B, and have rated each proposed project on the five

Exhibit 2.18 **Example Project Attributes and Measurement Scale**

Attribute	Measurement Scale							Attribute Weight (w_i)
1. Does project increase market share?	unlikely	1	2	3	4	5	likely	30%
2. Is new facility needed?				yes		no		15%
3. Are there safety concerns?			likely		unsure		no	10%
4. Likelihood of successful technical development?	unlikely	1	2	3	4	5	likely	20%
5. Likelihood of successful commercial development?	unlikely	1	2	3	4	5	likely	25%

attributes in Exhibit 2.18. Hypothetical ratings for each of the five attributes as well as linear transformed values are indicated in Exhibit 2.19. Given the attribute weights (w_i) in Exhibit 2.18, the overall project score (V_j) for Project A is calculated as follows:

$$\begin{aligned} V_A &= w_1v_1(x_1) + \cdots + w_5v_5(x_5) \\ &= 0.3(0.75) + 0.15(0.25) + 0.10(0) + 0.2(0.75) + 0.25(0) \\ &= 0.413. \end{aligned}$$

Using a similar approach, the score for Project B is 0.525.

Based on the responses to the attributes and given weights, Project B has a higher overall score (0.525) implying that Project B would be favored over Project A. But readers should be aware that these scores are based on many assumptions, including the selected Likert-type scale, the use of a linear transformation, definition of attribute weights, and the additive model used to aggregate the weighted responses into a single score. Changes in any of these assumptions could affect the value of the overall scores. Furthermore, it is not clear how the difference in overall scores should be interpreted; while Project B appears to be the preferred project, the degree of preference is uncertain.

Exhibit 2.19 **Example Project Scores**

Attribute	#1	#2	#3	#4	#5
Weight	0.3	0.15	0.1	0.2	0.25
Responses					
Project A	4	Yes	Likely	4	1
Project B	2	No	Unsure	3	4
Linear transformed scale					
Project A	0.75	0.25	0	0.75	0
Project B	0.25	0.75	0.5	0.5	0.75

Like any methodology, ranking and scoring methods can be helpful in improving the understanding of project differences but should be used with caution given the subjectivity involved in responding to the various ranking questions.

2.8 Evaluating Project Portfolios

LO 2.7 Define the role of project portfolios and the relationship between project selection and project portfolios.

2.8.1 Importance of Project Portfolios

New project proposals should be evaluated with respect to an organization's existing project portfolio. In this respect, several questions should be considered before considering any new project.

- Is the proposed project consistent with the goals and mission of the organization?
- Do the projects represent a mix of long-term and short-term projects?
- How does the proposed project affect the organization's overall resource constraints?
- What is the impact of the proposed project on the organization's cash flows?
- Is the project portfolio sufficiently diversified to reflect the organization's risk target; that is, does it contain projects that reflect a mix of new product and process development, market diversification, and a balance of technologies?
- Does the proposed project better position the portfolio for the current and future economic environment?

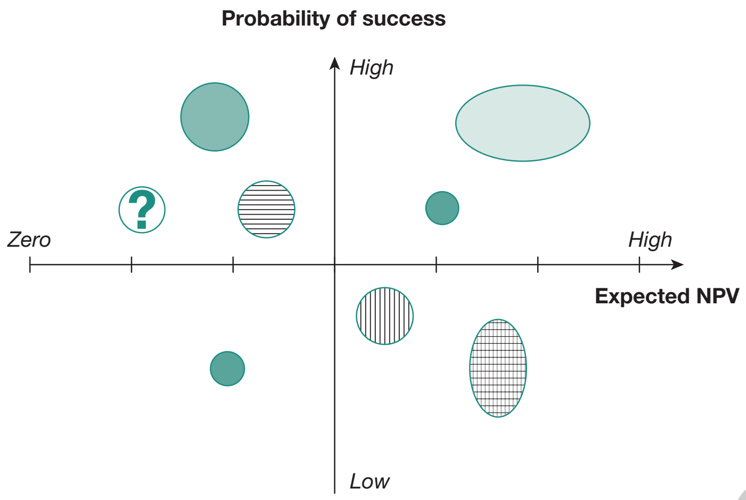
What happens when managers do not consider new projects from a portfolio perspective? Wheelwright and Clark described a scenario in a large scientific instruments company.[12] Motivated by rising budgets and declining numbers of successful projects, the company investigated and discovered that they had 30 development projects under way, far more than the company could support. Since most of the projects were delayed and overbudget, engineers and workers moved quickly from project to project, resulting in a crisis atmosphere that further delayed projects and compromised on quality. According to Wheelwright and Clark, most of the projects had been selected on an ad hoc basis by engineers who found the problems challenging, or by the marketing department who were reacting to customer demands. Few of the projects contributed to the company's strategic objectives. After analyzing its project portfolio, the company reduced its project portfolio to eight commercial development projects.

Assume that each project proposal is assigned an overall score representing its potential value (e.g., NPV, E(NPV), a measure V_j from a scoring or ranking model, or other metric). Using this score, we can rank-order the proposals under consideration[*] and select projects until resource or other constraints are no longer satisfied. This approach, however, fails to consider several important issues, including possible interrelationships among projects as well as the risk profile of the portfolio.

Given measures of risk and benefit (value) for each project, proposed projects can be located on a risk–return graph to visualize the portfolio composition. A two-dimensional version of this graph, known as a bubble diagram, is illustrated in Exhibit 2.20. There are many variations of bubble diagrams; some use three dimensions (e.g., NPV, risk, and expected duration), or various shapes and types of shading and colors to represent different types of projects. In Exhibit 2.20, for example, the type of shading represents a specific product line, while the size of the oval represents the resource requirements (e.g., R&D expenditures).

[*] Some organizations use a ratio, calculated by dividing the forecasted present value of the project by some constraining resource or initial investment, to rank order the proposals (similar to the profitability index described earlier in this chapter).

Exhibit 2.20 Bubble Diagram Illustrated



Note. NPV = net present value.

The bubble diagram in Exhibit 2.20 is a risk–reward graph similar to those used to analyze financial portfolios. These graphs are sometimes known as profile models in project selection and relate to the concept of efficient frontiers used in economics and finance. For example, consider the project indicated by a circle with a "?" inside. Since there is another project lying immediately to the right of this project that has a greater expected NPV but the same level of risk (measured by the probability of success), the project to the right dominates the first project that offers a greater return at the same risk level. Any project on this graph that is dominated by another project does not lie on the efficient frontier and is therefore unlikely to be adopted.

2.8.2 Mathematical Programming Model That Defines a Project Portfolio

The project portfolio selection problem can be formulated as a mathematical programming model. To define this model, we initially assume the values of individual projects are independent and the value of the portfolio is additive (i.e., the value of the overall portfolio is the sum of the projects' values). Following our initial discussion, we will show how these assumptions can be relaxed in a more realistic model.

Following our previous discussion on ranking and scoring methods, we assume that a score for each jth project, denoted by V_j, represents the relative value of each project when fully funded. Initially, we assume we can partially fund any project; that is, we want to find the decision variables

$$y_j = \text{percentage of project } j \text{ funded},$$

where $0 \le y_j \le 1$. We assume the value of the project is proportional to the percentage of the project funded; that is, the value of the jth project is equal to $V_j y_j$. Given n possible projects, we want to find the project portfolio that maximizes total value of the projects selected; that is, we want to maximize $\sum_{j=1}^{n} V_j\, y_j$.

Any number and type of constraints can be included in our model. For example, let's assume the organization is concerned with expenses and payments over the next 5 years. As a result, they impose the following budget constraints for each year $t = 1, \ldots, 5$:

$$\sum_{j=1}^{n} F_{jt}\, y_j \le B_t \quad \text{for all } t = 1, \ldots, 5,$$

where F_{jt} denotes the forecasted (outgoing) cash flow for the jth project in year t, and B_t denotes a budget constraint in year t. For example, let's assume we have a set of five possible projects {A, B, C, D, E}. In the first year, we have a budget constraint that limits the total cash flow out of the organization during the year to a maximum of $2.3 million. The forecasted cash flows in this year for the five possible projects are as follows:

$$F_{A1} = \$1.2\text{M}$$
$$F_{B1} = -\$0.25\text{M}$$
$$F_{C1} = \$0.8\text{M}$$
$$F_{D1} = \$0.4\text{M}$$
$$F_{E1} = \$1.0\text{M}$$

Note that the forecasted cash flow for Project B is negative (–$0.25 million), indicating that this project would generate a negative expense or revenue in Year 1, which could be used to offset the positive expenses associated with the other projects. Then the budget constraint for year $t = 1$ could be written as

$$\$1.2\text{M}\ y_A - \$0.25\text{M}\ y_B + \$0.8\text{M}\ y_C + \$0.4\text{M}\ y_D + \$1.0\text{M}\ y_E \le \$2.3\text{M},$$

where M denotes million.

To simplify our model, we assume the cash flows are proportional to the percentage of the project that is funded; for example, if we fund Project C at 40% (i.e., $y_C = 0.4$), then the forecasted expense for this project in Year 1 will be $0.4 \times \$0.8\text{M} = \$0.32\text{M}$. In the following example, we will show how a linear programming model can be constructed using the Solver function in Excel to select and fund projects that maximize the value of the project portfolio.

EXAMPLE 2.9

FINDING THE MAXIMUM VALUE OF THE PORTFOLIO USING EXCEL SOLVER

Consider the two projects discussed in the preceding section on ranking and scoring methods. Using the responses and attribute weights indicated in Exhibit 2.21, the maximum score for Project A is 0.413 and for Project B is 0.525 (assuming full funding).

Exhibit 2.21 Cash Flows for Two-Project Portfolio Selection Problem

	Year (t)				Max Project Score
	1	2	3	4	
Project A	$50	$42	$35	$15	0.413
Project B	$75	$62	($10)	($65)	0.525
Budget constraints	$100	$75	$30	$20	

Note. All values are in $ millions. Max = maximum.

Assume that both projects are expected to generate cash flows for 4 years as indicated in Exhibit 2.21. The budget constraints for each year (maximum allowed cash outflows) are also indicated in Exhibit 2.21. Note that the revenues generated by Project B might be used to offset some of the expenses associated with Project A in Years 3 and 4.

In this example, we have two decision variables:

y_A = level of funding (%) for Project A

y_B = level of funding (%) for Project B

We assume that the value of a project is the maximum possible score (e.g., 0.413 for Project A) times the percentage of funding for that project. We want to find the optimal funding levels for both projects that maximize the value of the project portfolio:

$$\text{Maximize } V_A y_A + V_B y_B = 0.413 y_A + 0.525 y_B$$

subject to the following constraints:

$$\$50\text{M}y_A + \$75\text{M}y_B \leq \$100\text{M} \text{ (Year 1 budget constraint)}$$

$$\$42\text{M}y_A + \$62\text{M}y_B \leq \$75\text{M} \text{ (Year 2 budget constraint)}$$

$$\$35\text{M}y_A - \$10\text{M}y_B \leq \$30\text{M} \text{ (Year 3 budget constraint)}$$

$$\$15\text{M}y_A - \$65\text{M}y_B \leq \$20\text{M} \text{ (Year 4 budget constraint)}$$

$$0 \leq y_A, y_B \leq 1$$

To solve this problem using Solver, we created the Excel spreadsheets in Exhibit 2.22; the Solver model that accompanies these spreadsheets is also indicated. The initial spreadsheet indicates the forecasted cash flows for Projects A and B for 4 years assuming that each project is fully funded at 100%. Positive numbers indicate expenses or cash flows out of the company; negative numbers indicate earnings or cash flows into the company. Note that earnings from Project B can be used to offset expenses from Project A in Years 3 and 4. The maximum value of each project is also indicated in this spreadsheet (assuming that each project is fully funded at 100%).

In the second spreadsheet, the decision variables (y_A and y_B) and resulting cash flows are indicated. The total annual cash flows (the sum of the cash flows in each year for Project A and Project B) are also indicated. In the solution in Exhibit 2.22, Project B is funded at 53%; as a result, the cash flow in Year 1 for Project B is 0.53 × \$75M = \$40M. The project score for Project B is equal to 0.53 × 0.525 = 0.279.

There are two sets of constraints in the Solver model. First, the decision variables must be less than or equal to 1 (since funding levels are expressed as percentages). Second, the total cash flows for each year cannot exceed the given annual budget limit (e.g., \$100 million in Year 1, \$75 million in Year 2, etc.). We want to maximize the sum of the project scores (the value of the portfolio). Since the linear programming (LP) model has only linear constraints, the Simplex algorithm can be used (an option in Solver).

The optimal project funding levels that maximize the value of the portfolio are given in Exhibit 2.22; as indicated, the company would fund Project A at 100% and Project B at 53% to maximize the value of the portfolio. It is interesting to note that Project B—the more valuable project by the ranking and scoring model—is the project that is not fully funded. But again, this is due to the trade-offs between the relative values of the two projects and the interaction with the budget constraints.

Exhibit 2.22 Spreadsheet Model for the Two-Project Portfolio Selection Problem

	Year (*t*)				Max Project
	1	2	3	4	Score
Project A	\$50	\$42	\$35	\$15	0.413
Project B	\$75	\$62	(\$10)	(\$65)	0.525
Budget constraints	\$100	\$75	\$30	\$20	

Spreadsheet Model:

		Annual Cash Flows				
Decision Variables	Percent Funded	1	2	3	4	Project score
y_A	1.00	\$50	\$42	\$35	\$15	0.413
y_B	0.53	\$40	\$33	(\$5)	(\$35)	0.279
	Total Annual Cash Flow	\$90	\$75	\$30	(\$20)	0.692 ← Total Portfolio Score
	Annual Budget Limit	\$100	\$75	\$30	\$20	

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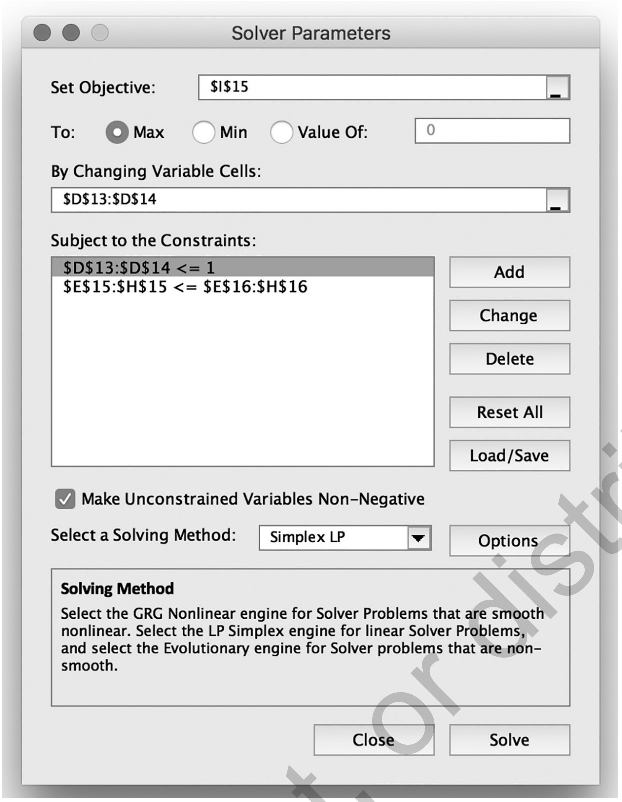


In some cases, projects cannot be funded at various levels; they must either be selected or not selected. In this case, the portfolio selection problem can be modeled using binary (0, 1) decision variables; that is,

$$y_j = \begin{cases} 1 & \text{if project } j \text{ is selected}, \\ 0 & \text{otherwise.} \end{cases}$$

In the above example, only Project B would be selected since Project A alone would violate the budget constraint in Year 3 and selecting both projects would violate the budget constraints in Years 1 and 2.

If projects have to be selected (or not), the problem of selecting the group of projects that maximize the portfolio value is known as a multidimensional knapsack problem. In the single-dimensional knapsack problem, we have a hypothetical knapsack of given size or volume, and we wish to pack items of known value and size into the knapsack to maximize the value of the selected items while not exceeding the size or volume limitations of the knapsack. In the multidimensional version of this problem, we assume that items are characterized by multiple characteristics (e.g., size, category, color, etc.). In this latter case, we want to select the set of items that maximize the value of the knapsack while simultaneously satisfying constraints on all dimensions (e.g., overall size, number of red items).

Several authors reported using a knapsack formulation and related models to formulate the project selection problem.[13,14,15] Beaujon et al. described an application that was implemented by the General Motors R&D Center to evaluate between 200 and 400 projects over a 1-year time horizon.[16] The GM model used both binary and continuous decision variables and was implemented and solved as a spreadsheet model.

EXAMPLE 2.10

A FOUR-PROJECT PORTFOLIO SELECTION PROBLEM

In this example, we will assume that we have four possible projects; two of these projects are IT projects and two projects are process improvement projects. Furthermore, we want to complete all the projects we select within a 5-year time horizon. The maximum value of these projects and their projected cash flows in each year are indicated in Exhibit 2.23. Management has specified that once a project is started, it must be continued until it is completed (i.e., a project cannot be interrupted once it is started).

In this case, management has specified that total funding on IT projects (i.e., Projects A and C) cannot exceed 40% of the total funding on this portfolio over the 5-year time horizon.

Initially, we assume all projects that are funded must start at the beginning of Year 1. We want to find how much to fund each project to maximize the value of the portfolio subject to the annual budget constraints and the requirement that IT projects cannot exceed 40% of total funding.

Exhibit 2.23 **A Four-Project Portfolio Selection Problem**

	Cash Flows					Max Project Score
	Year 1	Year 2	Year 3	Year 4	Year 5	
Project A (IT)	$40	$10	$20	$20		0.741
Project B	$65	$36	$30	$25	$30	0.845
Project C (IT)	$6	$8	$10			0.353
Project D	$20	$10	$20	$20		0.457
Available funds	$120	$40	$40	$55	$60	

Note. All values are in $ millions. Max = maximum.

Following the previous example, we have four decision variables:

> y_j = percentage of project j funded (where j = Projects A, B, C, and D).

Again, we let V_j denote the maximum value of a project (found using a ranking and scoring method) if the project is funded at 100%; thus, $V_1 = 0.741$, $V_2 = 0.845$, and so on, as indicated in Exhibit 2.23. We assume that the value of a project is proportional to its funding level (i.e., if $y_1 = 0.5$, then Project 1 has a value of $0.5 \times 0.741 = 0.3705$). Thus, the value of the portfolio that we want to maximize is equal to

$$\sum_{j=1}^{4} V_j y_j = 0.741 y_A + 0.845 y_B + 0.353 y_C + 0.457 y_D.$$

The budget constraints in this problem are similar to the budget constraints in the previous example; for year $t = 1$, the constraint would be algebraically stated as follows:

$$\$40My_A + \$65My_B + \$6My_C + \$20My_D \le \$120M \quad \text{for year } t = 1.$$

In general, the budget constraints for each of the 5 years are stated as

$$\sum_{j=1}^{4} F_{jt} y_j = B_t \quad \text{for year } t = 1, \ldots, 5,$$

where F_{jt} denotes the cash flow from project j in year t.

The constraint that total spending on IT projects cannot exceed 40% of total spending over the 5-year time horizon can be written algebraically as

(Continued)

(Continued)

$$\sum_{t=1}^{5}(F_{At}y_A + F_{Ct}y_C) \le 0.4\sum_{t=1}^{5}\sum_{j=A}^{D}F_{jt}y_j,$$

which can be simplified to

$$0.6\sum_{t=1}^{5}(F_{At}y_A + F_{Ct}y_C) \le 0.4\sum_{t=1}^{5}(F_{Bt}y_B + F_{Dt}y_D).$$

In addition, we add constraints that limit the decision variables y_j to values between 0 and 1 (since they are percentages). These constraints are algebraically stated as

$$0 \le y_j \le 1 \text{ for all } j = \text{Projects A, B, C, and D.}$$

The Excel spreadsheet, Solver model, and optimal solution for this problem are given in Exhibit 2.24. As indicated, only Projects A, B, and C would be funded at levels ranging from 35% to 52% to define an optimal portfolio with a score equal to 1.30.

In similar fashion, additional constraints can be added to restrict the number of workers needed in various categories (e.g., engineers, accountants, carpenters), the number of new hires needed, total spending on R&D, as well as balance within the portfolio. In one application, constraints were included for precedence (e.g., Project B cannot be selected unless Project A is also selected), forced selection (when outside commitments dictate that a project must be selected at some funding level), and an upper bound on additional spending.

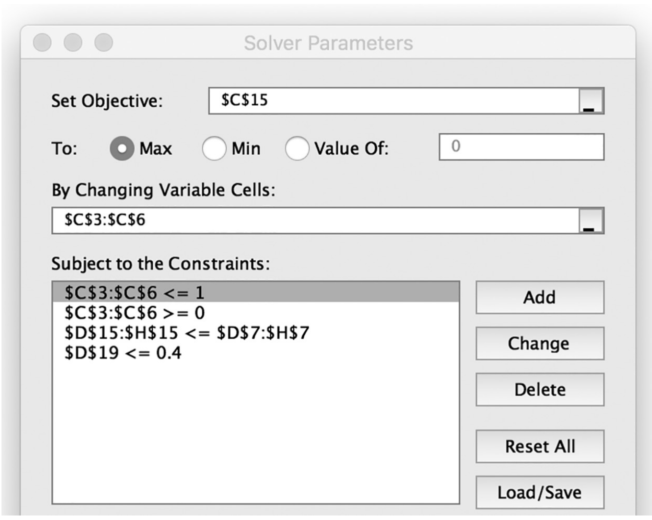
Exhibit 2.24 **Solver Model and Solution for Four-Project Portfolio**

	Project Score	*Cash Flows*					Total Spent
		Year 1	Year 2	Year 3	Year 4	Year 5	
Project A (IT)	0.43	$ 23.17	$ 5.79	$ 11.58	$ 11.58	$ -	$ 52.12
Project B	0.52	$ 39.90	$ 22.10	$ 18.42	$ 15.35	$ 18.42	$ 114.19
Project C (IT)	0.35	$ 6.00	$ 8.00	$ 10.00	$ -	$ -	$ 24.00
Project D	0.00	$ -	$ -	$ -	$ -	$ -	$ -
	1.30	$ 69.07	$ 35.89	$ 40.00	$ 26.93	$ 18.42	$ 190.31

Total spent on IT projects = $ 76.12

Total spent on all projects = $ 190.31

Proportion spent on IT projects = 40.0%



Note. All values are in $ millions.

EXAMPLE 2.11

DEFINING A PORTFOLIO WHEN PROJECT SELECTION AND TIMING ARE CONSIDERED

Extending the previous example, we show how a defer option can be included in the previous example and how this option may add value to a project portfolio. Specifically, we assume that the start time of any of the four projects indicated in Exhibit 2.24 can be delayed or deferred, with the requirement that (a) all projects that are selected for this portfolio must be completed by the end of Year 5 and (b) once a project is started, the funding level cannot be changed and the project must be continued until completed. We add these restrictions to reduce the complexity of the model with the caveat that all these restrictions can be relaxed.

Examining the problem in Exhibit 2.24, we note that our options are limited to delaying the start of Project A by 1 year, delaying the start of Project C by 1 or 2 years, and delaying the start of Project D by 1 year. Since there are two options for Project A, one option for Project B, three options for Project C, and two options for the start of Project D, there are a total of $2 \times 1 \times 3 \times 2 = 12$ alternatives that we must investigate. The alternative (found by trial and error) that resulted in the portfolio with the maximum value is given in Exhibit 2.25.

Clearly, the optimal portfolio with a defer option can never be any worse than the optimal portfolio without a defer option. As indicated in Exhibit 2.25, the value of the portfolio increases to 1.61 when the start of Project C is delayed to Year 3 and the start of Project D is delayed to the start of Year 2—an increase in value of almost 24%. This example illustrates the general concept that considering more options generally increases the value of an organization's portfolio.

Exhibit 2.25 **Solver Model and Solution for Four-Project Portfolio With Defer Option**

	Decision Variable	Value	Year 1	Year 2	Year 3	Year 4	Year 5	Max Project Score
Project A (IT)	A	0.706	$40	$10	$20	$20		0.741
Project B	B	0.329	$65	$36	$30	$25	$30	0.845
Project C (IT)	C	1.000			$6	$8	$10	0.353
Project D	D	1.000		$20	$10	$20	$20	0.457
Available funds			$120	$40	$40	$55	$60	

	Project (and Portfolio) Score	Cash Flow					
		Year 1	Year 2	Year 3	Year 4	Year 5	Total Spent
Project A (IT)	0.523	$28.23	$7.06	$14.12	$14.12	$0.00	$63.52
Project B	0.278	$21.42	$11.86	$9.88	$8.24	$9.88	$61.28
Project C (IT)	0.353	$0.00	$0.00	$6.00	$8.00	$10.00	$24.00
Project D	0.457	$0.00	$20.00	$10.00	$20.00	$20.00	$70.00
	1.61	$49.65	$38.92	$40.00	$50.35	$39.88	$218.80

Total spent on IT projects =	$87.52
Total spent on all projects =	$218.80
Proportion spent on IT projects =	40.0%

Note. All values are in $ millions. Max = maximum.

SUMMARY

LO 2.1 State why new projects should relate to strategic and operational goals.

It is important for organizations to choose the right projects to do and those that fit within the overall organizational objectives. Some strategies to consider when choosing projects include risk tolerance, cash flow, diversification of portfolios, and resource allocation. Projects can be classified as strategic (support the overall mission) or utility (improve efficiencies and effectiveness).

LO 2.2 Explain how numeric measures can be used to evaluate proposed risky projects.

Numeric measures can define the costs and benefits of particular projects. They are generally used in conjunction with other approaches to present a more complete picture. Numeric values discussed include the following:

- *Payback period:* The number of time periods (e.g., years) needed to recover the cost of the project.

$$\text{Payback period (years)} = \frac{\text{Estimated project cost}}{\text{Annual savings (or increase in revenues)}}.$$

- *NPV:* The sum of the DCFs over the estimated life of the project.

$$\text{NPV} = F_0 + \sum_{t=1}^{T} \frac{F_t}{(1+r)^t}.$$

- *IRR:* The discount rate that results in an NPV equal to 0.

$$F_0 + \frac{F_1}{(1+r)} + \frac{F_2}{(1+r)^2} = 0.$$

- *ARR:* The return on investment defined by average earnings divided by average initial investment.

$$\text{ARR} = \frac{\text{Annual cash inflow} - \text{Annual depreciation}}{\text{Initial investment}}.$$

- *PI:* The ratio of discounted future returns divided by the initial investment.

$$\text{PI} = \frac{\text{Present value of future cash flows}}{\text{Initial investment}}.$$

LO 2.3 Describe how risk-adjusted discount rates can be used to reflect changing levels of risk throughout a project's life.

Risk-adjusted discount rates allow assessment of alternatives or outcomes that could come up in a project. This will allow for determining the impact specific restraints may have on a project. It allows for assessing the impact of risk at the beginning of a project versus the end of the project; the risk varies over the life span of the project.

LO 2.4 Explain how to apply options thinking to the design and selection of proposed projects.

Options thinking allows assessment of a project at specific points in time to address any issues that may have changed or need to be reconsidered. This may be a change in resource allocation or schedule, for instance. This allows decisions to be made about moving forward with stages of a project before project completion. It allows more flexibility and can affect the value of the project.

LO 2.5 Describe the role and importance of stage gates.

The stage-gates approach is another technique that allows assessment of a project along the project life cycle allowing decisions to be made before moving to the next stage. This allows a proactive "go–no go" decision to be made at each stage before the next stage can begin.

LO 2.6 Explain how qualitative measures can be included when evaluating potential new projects.

Scoring or ranking methods can be used in addition to numerical measures to determine product validity. These techniques can assess qualitative factors such as consistency with mission statement, quality, safety, competitors, and so on.

LO 2.7 Define the role of project portfolios and the relationship between project selection and project portfolios.

When considering which projects to select, it is important to view all proposed projects as part of a portfolio. In the same way that individuals view their financial portfolios (with respect to goals, risk, etc.), project portfolios provide similar instruments for organizations. Defining and managing these portfolios may be the most important factor that determines the long-term viability of any organization.

KEY TERMS

SOLVED PROBLEMS

1. You are considering two possible projects (Project A and Project B) that would start at the beginning of next year. Your boss has indicated that she only wants to select one of these projects given resource constraints and uncertainties about the economy. She has asked you to evaluate each project and recommend which project you think the company should select.

You have made the following forecasts for each project. Project A would require an initial investment of $6.4 million at the beginning of next year and a second investment of $4 million at the beginning of the following year. The project would break even in the second year (i.e., earn zero) but would earn positive returns of $1.2 million, $3.5 million, $7.1 million, and $12.6 million in the following 4 years. (*Hint:* Treat the beginning of next year as Year 0.)

Project B would require an initial investment of $18 million at the beginning of next year but would not earn (or cost) anything until the end of Year 5 when you think it would return approximately $45 million.

You estimate that an appropriate annual discount rate is 14% based on your company's future projected performance. Furthermore, the chief financial officer (CFO) has indicated there is an inflation rate of 2.5% that should be factored into your calculations; he feels this rate will be fairly constant over the foreseeable future. The CFO has also indicated that the company uses discrete discounting and assumes all cash flows occur at the end of each year (except for the initial investments).

Your boss indicated you should consider the inflation rate–adjusted NPV, the IRR, and the PI when comparing these two projects. Based on these metrics, which project would you recommend? What other factors (other than these metrics) might be important when comparing these projects? How would your company's risk tolerance affect the possible decision?

Solution

Given the information in the problem, two spreadsheets can be developed for Project A and Project B. We first discount the cash flows based on the forecast inflation rate (2.5%) and then adjust these cash flows based on the real discount rate (14%). The calculations are indicated in Exhibit 2.26 as well as the NPV, IRR, and PI for both projects. The NPV was calculated using the formulas for discrete discounting given in this chapter; the IRR was calculated using the IRR function in Excel. The PI was calculated using the formula given in this chapter that is defined as the present value of all future cash flows divided by the initial investment.

Exhibit 2.26 Calculating Financial Metrics

Discount Rate r = 0.14

Inflation rate (i) = 0.025

	NPV (Discrete Discounting)	IRR	Profitability Index
Project A	1.02	0.164	1.16
Project B	2.66	0.172	1.15

Project A

Year	Cash Flows	Inflation-Adjusted Cash Flows	Present Value
0	$6.4	$6.40	$6.40
1	$4.0	$3.90	$3.42
2	$0.0	$0.00	$0.00
3	$1.2	$1.11	$0.75
4	$3.5	$3.17	$1.88
5	$7.1	$6.28	$3.26
6	$12.6	$10.86	$4.95
		$11.12	$1.02

Project B

Year	Cash Flows	Inflation-Adjusted Cash Flows	Present Value
0	$18.00	$18.00	$18.00
1	$0.00	$0.00	$0.00
2	$0.00	$0.00	$0.00
3	$0.00	$0.00	$0.00
4	$0.00	$0.00	$0.00
5	$45.00	$39.77	$20.66
		$21.77	$2.66

Note. All values are in $ millions. NPV = net present value; IRR = internal rate of return.

Based on these calculations, it appears that Project B is superior with respect to NPV and IRR although Project A has a slightly higher PI. However, Project B appears to be much riskier than Project A since it doesn't earn any positive return until the end of Year 5 when the earnings projection is much less certain.

Despite the fact that the expected NPV is higher for Project B, it is not clear that you would automatically choose this project if you are risk averse (remembering that expected values or averages assume that the decision maker is risk neutral).

2. Cody Parker is a senior manager who is evaluating four possible projects (A, B, C, and D). Cody can fund any project in part or in total; however, he cannot change the funding percentage once the project has started. The costs and revenues associated with any project are a linear function of the funding percentage; for example, if Project A is funded at 40%, it would cost (0.4 × $14M =) $5.6M in Year 1 and generate a value to the company's portfolio of (0.4 × 10 =) 4. Also, once a project has started, it cannot be stopped until completed.

If the projects are fully funded (at 100%), the cash flows for each project over the next 3 years are indicated in Exhibit 2.27. The positive numbers in the table indicate expenses (cash flows out) while the negative numbers indicate payments to the company (cash flows in). In addition, each project has been valued using a ranking/scoring method described in this chapter; the maximum value of each project is indicated in the table (e.g., Project A would be worth 10 points if fully funded).

Project A is a utility project to repair and upgrade the maintenance facility, but it will not generate any positive cash flow to the company (thus, only costs are associated with that project). The other three projects represent new products or services that will generate positive cash flows to the company in the third year.

Cody wants to maximize the value of his company's project portfolio over the next 3 years since that will determine his bonus. However, Cody has stated that the total cash flows in each year cannot exceed the budget constraint that was specified by the company's CFO. For example, no more than $50 can be spent in Year 1 as indicated by the budget constraint for Year 1.

Exhibit 2.27 **Forecast Cash Flows**

	Year 1	Year 2	Year 3	Max Project Score
Project A	$14	$12	$10	10
Project B	$23	$18	$44	2.5
Project C	$6	$8	$16	4
Project D	$20	$11	$20	3.5
Budget constraint	$50	$40	$0	

Note. All values are in $ millions. Max = maximum.

Cody wants to select a project portfolio that maximizes the total portfolio score, subject to the budget constraints. Each project can be funded between 0% (no funding) to a maximum of 100% (fully funded).

a. Given the budget constraints, which projects should Cody recommend for funding? At what level?

b. Cody's boss has reconsidered Project A, the utility project to repair the roof. She now feels that only offers a value of 2.0 if fully funded (not 10.0). How does this change the composition of the project portfolio?

c. If each project can only be fully funded at 100% or not funded at all (0%), how does this change Cody's portfolio selection? Which projects would he now select? (Assume that the maximum value of Project A is 10.)

Solution to Part (a)

This problem can be solved as a linear programming problem using Solver in Excel (or any other linear programming algorithm). To formulate a Solver model, we need to create a table that indicates the decision (or changing) variables as well as the cash flows (given the percentage funded) and the corresponding project value. This table is indicated in Exhibit 2.28.

Exhibit 2.28 **Optimal Allocation to Maximize Portfolio Value**

	Percent Funded	Year 1	Year 2	Year 3	Project Score	
Project A	1.00	$14.0	$12.0	$10.0	10.00	
Project B	0.43	$10.0	$7.8	$19.1	1.09	
Project C	1.00	$6.0	$8.0	$16.0	4.00	
Project D	1.00	$20.0	$11.0	$20.0	3.50	
Total spent		$50.0	$38.8	$45.1	18.59	Total portfolio value

Note. All values are in $ millions.

The Solver model maximizes the sum of the project scores that represent the value of the portfolio by changing the percentage funding for each project. The cash flows are adjusted accordingly. The optimal solution indicates that the maximum possible portfolio value is 18.59; Projects A, B, and D are fully funded, while Project B is only funded at a 43% level.

Solution to Part (b)

The solution to this part is similar to the solution in Part (a) with the difference that the maximum value for Project A is now 2 (instead of 10). The optimal solution is indicated in Exhibit 2.29; the optimal portfolio is now reduced to 10.59 although the projects remain funded at the same level. This solution indicates that a decision maker should always conduct a sensitivity analysis when using any mathematical model as it may not be intuitive that the optimal solution remains the same when the value of Project A drops significantly.

Exhibit 2.29 Optimal Project Allocations

	Percent Funded	Year 1	Year 2	Year 3	Project Score	
Project A	1.00	$14.0	$12.0	$10.0	2.00	
Project B	0.43	$10.0	$7.8	$19.1	1.09	
Project C	1.00	$6.0	$8.0	$16.0	4.00	
Project D	1.00	$20.0	$11.0	$20.0	3.50	
Total spent		$50.0	$38.8	$45.1	10.59	Total portfolio value

Note. All values are in $ millions.

Solution to Part (c)

The solution in this part is found by specifying that the decision (or changing) variables must be binary (i.e., only 0 or 1) by adding a constraint in Solver that the decision variables must equal "bin." The constraints that the decision variables must not exceed 1 can be deleted. The optimal solution in this case indicates that Projects A, C, and D are selected for full funding while Project B is not funded at all. The value of the resulting portfolio is 17.50 as indicated in Exhibit 2.30.

Exhibit 2.30 Optimal Project Allocations

	Percent Funded	Year 1	Year 2	Year 3	Project Score	
Project A	1.00	$14.0	$12.0	$10.0	10.00	
Project B	0.00	$0.0	$0.0	$0.0	0.00	
Project C	1.00	$6.0	$8.0	$16.0	4.00	
Project D	1.00	$20.0	$11.0	$20.0	3.50	
Total spent		$40.0	$31.0	$26.0	17.50	Total portfolio value

Note. All values are in $ millions.

REVIEW QUESTIONS

1. Suppose your company has more than a dozen projects to choose from—but can only select a limited few. What criteria would you suggest for ranking the projects? How would you ultimately decide which projects to select?
2. A popular metric for evaluating proposed projects is ROI (return on investment). How does ROI relate to NPV and ECV that are defined in this chapter? Which of these metric(s) would you recommend? Defend your answer.
3. What does "options thinking" mean to you? How would you implement an "options thinking" approach to a new IT app development project?
4. How do the concepts of stage gates and "options thinking" relate to each other?

5. Your organization has recently adopted a statement that sustainability will be an important part of the organization's focus. How would you incorporate this into your decision-making process when evaluating new projects? (As part of this discussion, consider how you would define sustainability.)
6. What are the limitations associated with numerical methods such as ROI and DCFs? How do you address these limitations when evaluating newly proposed projects?
7. Your company is considering the development of a new product that has high market potential but may be very expensive to develop. How would you approach such a project proposal?

STUDY PROBLEMS

Problem 2.1. Assume you have successfully completed the R&D phase of an NPD project; this phase took several years and cost an estimated $30 million but resulted in a successful prototype product. You and your company are now ready to start the market development and research phase of your NPD project. It is estimated the market development and research phase of this project will take 2 years and cost $11.5 million per year. There is an 80% probability that the market development and research phase will indicate that a viable market exists for your new product.

Before your company can begin the market development and research phase, however, a long-time rival announced that it plans to market a similar product in 1 year that will directly compete with your newly developed product. Your company feels that there is a 60% probability that your new product will be superior to your competitor's product.

If your company's product is superior to your competitor's product and the market development phase indicates that a viable market exists, you will earn a net profit of $10 million per year for 10 years. If your product is inferior to your competitor's product, you will terminate the project. Assuming a discount rate of 14%, calculate the expected NPV of your new product assuming that you proceed immediately with the marketing development and research phase.

In analyzing this problem, you should make the following assumptions. First, if you learn that your competitor's product is better than your product after 1 year of market development, you will terminate the project and not incur the market development cost ($11.5 million) for the second year. Second, assume that all cash flows occur at the end of the year.

a. Compare your results with the case when you decide to wait for 1 year (to learn more about your competitor's product) before proceeding with the market development and research phase. If you postpone the market development phase by a year, however, and your product is the superior product (and a viable market exists), it will only have a 9-year life span. What do you think is your best strategy?
b. The CFO of your company thinks that a lower discount rate would be appropriate if you waited for 1 year before making a decision whether to proceed with this product. If the discount rate is 12% in this case, how does this affect your decision to proceed or to wait until next year?

Problem 2.2. A small company is considering three possible projects (A, B, and C) over the next 5-year time horizon. They have used extensive questionnaires and evaluations of each possible project and have arrived at a relative ranking of each project (a higher score is a more favorable project). Furthermore, they have estimated the cash flows needed for each project; positive numbers indicate cash flow payments and negative numbers indicate cash receipts (e.g., earnings). This information is summarized in Exhibit 2.31.

Exhibit 2.31 Forecast Project Cash Flows and Maximum Project Values

Parameters: Cash Flows (If Funded at 100%)

	Project Score (Max Value)	Year 1	Year 2	Year 3	Year 4	Year 5
Project A	22	$75	$55	$50	$20	($5)
Project B	19	$80	$36	($5)	($35)	($40)
Project C	14	$45	$40	$45	$50	
	Budget	$125	$80	$50	$40	$0

Note. All values are in $ millions. Max = maximum.

The company has limited capital and does not want to increase its debt; thus, the chief executive officer (CEO) has imposed budget constraints on the net funds that the company can afford to spend each year. These budget limitations are indicated in the row "Budget." Note that in some years (e.g., Year 3), earnings from Project B might offset the expenses of the other projects.

The CEO knows she cannot fund all three projects at 100%; however, she can fund projects at some proportion less than 100%. She assumes the project value earned is proportional to the percentage funded (i.e., if Project A is funded at 40%, it would be worth 0.40 × 22 = 8.8 to the company). She assumes that cash flows are similarly proportional to the percentage of the project that is funded.

a. Assuming that the value of the project portfolio is additive (over the three projects), what percentage of each project should the CEO fund? What is the resulting value of the project portfolio? (*Hint:* Use linear programming and Excel Solver for this problem.)

b. The CEO decides that both Projects A and C cannot be funded; that is, at most one of these projects can be funded. How does this change your recommendation?

c. A consultant has told the CEO that he feels the score associated with Project A is not accurate and that Projects A and B are comparable (i.e., have the same score). Does this make a difference in your solution?

d. Using the project scores in Part (a), consider the possibility of delaying the start of Project C by 1 year. Would you consider such a delay option? Why or why not?

Problem 2.3. The Trid Soap Company is developing a radically new soap powder that is expected to take 3 years to develop and cost approximately $6 million per year. At the end of the 3 years, Trid will know if the product is a technical success; at the present time, Trid managers estimate that there is an 80% likelihood that they will be successful in developing the soap powder. Assuming the R&D succeeds, Trid can launch the product in Year 4 at an estimated cost of $5.5 million. If launched, the marketing VP (Vice President) estimates that the new product would be a commercial success with probability 0.6; if it is commercially successful, it would earn gross revenues of $15 million per year for 5 years. If not a commercial success, the new soap powder would only earn an estimated $2 million per year. Assuming an annual discount rate of 12%, what is the NPV of this project? Would you recommend that Trid proceed with this project?

Problem 2.4. In Problem 2.3, assume the first phase (the R&D phase) has proceeded very well; a successful prototype soap powder was successfully developed at the end of Year 3 (at a cost of $6 million each year). At the beginning of the fourth year (before the company begins developing test marketing), a long-time rival announces that it will have a similar product available next year.

Trid Soap Company managers feel there is a 75% probability that their product is superior to their competitor's product. If the company's product is superior, they will earn a net profit of $12 million per year; otherwise, the company will lose $3 million per year. Trid senior managers are considering the possibility of suspending the project for a year to get more information on their competitor's product before launching their new soap powder. If they wait, however, and their product is superior, the life span of the new product would be reduced to 4 years. What would you recommend in this case (the cost to launch the new product is still $5.5 million)? (Assume an annual discount rate of 12%.)

Problem 2.5. You are considering two possible projects (Project A and Project B) that could start on January 1, 2020. Your boss has indicated that she only wants to start one of these projects given resource constraints and asked you to evaluate each project and recommend which project you think the company should start. You have made the following forecasts for each project.

Project A would require an initial investment of $20 million on January 1, 2020, and a second investment of $10 million on January 1, 2021. The project would break even in the following year (2022) but would earn a positive return of $12 million in 2023 and $40 million in 2024.

Project B would require an initial investment of $25 million on January 1, 2020, but would return a net positive cash flow of $2 million, $4 million, $8 million, $12 million, and $22 million in the next 5 years.

You estimate that an appropriate annual discount rate is 13% based on your company's future projected performance. Furthermore, the CFO has indicated that there is an inflation rate of 2% that should be factored into your calculations; he feels that this rate will be fairly constant over the foreseeable future.

Your boss indicated that you should consider the inflation rate–adjusted NPV and the IRR when comparing these two projects. Based on these metrics, which project would you recommend? What other factors (other than NPV and IRR) might be important when comparing these projects?

Problem 2.6. You work for Mango Computer Company, which is considering an NPD project to develop a new tablet computer. As part of their planning process, the development team is considering whether or not to outsource the production of the screen. The estimated cost of the screen depends on the market demand of the new tablet that is uncertain at this time. If the market demand is high, the development team estimates that they can invest in special robotic equipment that will result in a reduced variable (unit) cost.

You have been asked to consider the problem of outsourcing the production of the screen. After considerable analysis, you have estimated the unit costs as a function of future demand (low, average, or high) of the tablet computer and the probability estimates of future demand for the next 5 years (Exhibit 2.32).

Exhibit 2.32 **Predicted Screen Costs as a Function of Demand and Production Source**

	Future Demand for New Product		
	Low	*Average*	*High*
Produce in-house	$140	$120	$90
Outsource	$100	$110	$160
Probability	**0.1**	**0.6**	**0.3**

Note. All values are in $ millions.

a. Prepare a decision tree that describes the problem of deciding whether or not to outsource the production of the computer screen.

b. Based on your probability estimates of future demand, would you recommend outsourcing the production of the screen or producing it in-house?

c. A consultant has stated that he can forecast future demand with complete certainty. What is the maximum amount that you would pay him for this information?

d. What other factors might you consider when making a decision to outsource part or all of a new product, besides expected costs?

Problem 2.7. Jim is a senior manager who is considering four projects for possible adoption; two of the projects (A and C) are IT projects. Jim has estimated the cost per year for each project; these cost estimates are indicated in Exhibit 2.33. The company can fund any project in part or in total; however, it cannot change the funding percentage once the project has started (e.g., if Project A is funded at a 50% level, then this project will cost $20 million in the first year, $5 million in the second year, and $10 million in the third and fourth years). Also, once a project has started, it cannot be stopped until it is completed.

Exhibit 2.33 **Forecast Cash Flows and Project Values When Project Is Fully Funded**

	1	2	3	4	5	Project Score
Project A (IT)	$40	$10	$20	$20	—	0.741
Project B	$65	$36	$30	$25	$30	0.845
Project C (IT)	$6	$8	$10	—	—	0.353
Project D	$20	$10	$20	$20	—	0.457
Available funds	$120	$40	$40	$55	$60	

Note. All values are in $ millions.

The value of each project to the company is indicated by the project score; if the project is only partially funded, the project score is scaled proportionately (e.g., if Project A is funded at a 50% level, the company gains $0.5 \times 0.741 = 0.3705$).

Jim wants to select a project portfolio that maximizes the total portfolio score, subject to the budget constraints. In addition, top management has stated that funding on IT projects should not exceed 40% of *total* funding over the next 5 years (Exhibit 2.33).

a. Given the constraints, which projects should Jim recommend for funding? At what level? (Assume that no project can be funded at more than 100%.) (*Hint:* Use Excel solver and linear programming for this problem.)

b. Assume that Jim has the choice of delaying the start of some projects as long as all selected projects can be completed in 5 years. However, once a project is started, it cannot be stopped until it is completed. Should Jim recommend that any project(s) be delayed and, if so, which projects and how long?

Problem 2.8. Assume in Problem 2.7 that you can only select a project in its entirety or not at all (i.e., you can only fund a project at 0% or 100%). How does this change your decisions in Problem 2.7?

CASELET 2.1 AFFORD MOTOR COMPANY

You have taken a job with Afford Motor Company. The CEO, Sandy Shores, has proposed that Afford Motors develop, manufacture, and sell an electric car that she claims will present a great business opportunity for Afford Motors and help slow the negative impacts of climate change.

After investigating numerous prototypes, you and your project team have determined there are two cars that should be seriously considered: Model A and Model B. Characteristics of these two prototypes are indicated in Exhibit 2.34.

Exhibit 2.34 Characteristics of Proposed Electric Cars (Models A and B)

	R&D and Tooling Costs (in $USD)	MSRP	Average Variable Cost	Range Between Charges (km)	No of Passengers (Including Driver)	Crash Test Safety Rating*
Model A	$100,000,000	$17,500	$5,000	50	2	4
Model B	$140,000,000	$26,000	$7,600	80	4	8.5

**Crash test safety ratings are based on information provided by the National Highway Traffic Safety Administration; ratings are provided on a scale from 1 to 10 with higher numbers representing relatively safer vehicles.*

Note. All values are in $ millions. MSRP = manufacturer-suggested retail price.

The market research department has estimated that number of electric cars demanded will be a function of the future price of gasoline as well as the car's characteristics. To forecast the future price of gas, you hired Ed Price, a well-known economist and consultant. Ed estimates that the future price of gas (relative to today's prices) could be falling with a probability of 0.3, stable with a probability of 0.45, or rising with a probability of 0.25. His estimates of annual sales (in number of cars) as a function of changing gas price levels is indicated in Exhibit 2.35.

Exhibit 2.35 Forecast Sales of Proposed Electric Cars as a Function of Future Gasoline Prices

	Price of Gas (Next 9 Years)		
	Falling	***Stable***	***Rising***
Model A	1,000	1,500	2,200
Model B	700	1,600	2,750
	0.3	*0.45*	*0.25*

Note. All values are in $ millions.

Model A is based on a currently available technology; as a result, senior managers feel confident that it could be ready for sales in 1 year if you commit the R&D/tooling immediately. On the other hand, Model B is based on newer technologies that have been developed but not thoroughly tested; as a result, Model B would require 2 years of development and tooling before it would be ready for the market. If you decide to proceed with Model B, however, you would only need to commit 50% of the development and tooling costs at this time (the remainder would be required after 1 year). Experts in the automotive industry feel that Model A would have an expected life span of 9 years, but Model B (since its introduction would be later than the introduction of Model A) would only have an 8-year life span.

The CEO has said that Afford Motors can undertake the development of at most one electric car as the company lacks sufficient resources to develop both models and she is concerned that the two electric cars would compete in a limited market and reduce overall sales. Sandy also indicated that Afford will market these cars directly to individual consumers (assume that cars sell at their MSRP [manufacturer-suggested retail price]). Sandy also feels that a discount rate of 12% is appropriate for these potential projects based on her estimate of the Afford Motor weighted average cost of capital (WACC).

You must make a decision shortly on whether or not to proceed with either (or neither) of the two electric car models.

a. Based on Afford's expected (discounted) profit over the forecasted life of the electric cars, what would you recommend? Should Afford proceed with the development of Model A, Model B, or neither? Support your answer. Assume that all cash flows occur at the beginning of each year.

b. The economist, Ed Price, has told you he will be able to determine (with certainty) after 1 year the price trend of gas for the next 9 years (before you would have to commit to the second half of Model B's development and tooling cost if you had started the development of Model B this year). Does this affect your decision? If so, how and why? Using this information, what is the value of Dr. Price's information?

NOTES

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