illustration of the calculation of NPV is given below in Example 17.29, following a discussion of the IRR method.

Investor's Rate of Return (IRR or DCFRR)

The *investor's rate of return* (IRR), also called the *discounted cash flow rate of return* (DCFRR), is the interest rate that gives a net present value of zero. Since the net present value is a complex nonlinear function of the interest rate, an iterative procedure (easily accomplished using a spreadsheet) is required to solve

$$\text{NPV}\{r\} = 0 \qquad \text{for } r \tag{17.49}$$

When comparing proposed processes, the largest IRR is the most desirable. Note, however, that sometimes the process having the largest IRR has the smallest NPV. In many cases, especially when the alternatives have widely disparate investments, both the NPV and the IRR are effective measures. This is especially true when the alternatives are comparable in one measure but are very different in the other. The following example computes both the NPV and the IRR.

EXAMPLE 17.29

(Example 17.14 Revisited)

For the process considered in Example 17.14, but with MACRS depreciation for a 5-yr class life as determined in Example 17.27, calculate, over an estimated life of 15 yr, including years 1997–1999 when the plant is being constructed (a) the NPV for a nominal interest rate of 15% compounded annually and (b) the nominal interest rate for the IRR method (i.e., for NPV = 0). For the first 2 yr of plant operation, when at 45 and 67.5% of capacity, the cost of production, exclusive of depreciation, is \$55 million and \$78 million, respectively.

SOLUTION

a. The cash flows are shown in the following table in millions of dollars per year. Note that the total depreciable capital of \$90 million is divided into three equal parts for the first 3 yr. The working capital of \$40 million appears in the third year. Plant startup costs in the years 2000 and 2001 are not included and no salvage is taken at the end of the project. In the year 1999, the investment in millions is $-\$30 + -\$40 = -\$70$. The discount factor is $1/(1 + 0.15)^2 = 0.7561$. Therefore, the PV is $0.7561(-70) = -52.93$ or $-\$52.93$ million. Instead of showing negative signs in the table, negative values are enclosed in parentheses. When added to the $-\$56.09$ million for the cumulative PV for 1998, a cumulative PV of $-\$109.02$ million is obtained for 1999. In the first year of plant operation, 2000, sales revenue is \$75 million, MACRS depreciation is \$18 million, and production cost exclusive of depreciation is \$55 million. Therefore, pre-tax earnings is $75 - 55 - 18 = \$2$ million. The combined federal and state income tax is $0.37(2) = \$0.74$ million. This gives an after-tax or net earnings of $2 - 0.74 = \$1.26$ million. The cash flow for year 2000 is $1.26 +$ the 18 depreciation allowance $= \$19.26$ million. The discount factor for that year is $1/1.15^3 = 0.6575$. Therefore, the PV for 2000 is 0.6575(19.26) or \$12.67 million. When added to the cumulative PV of $-\$109.02$ million, a cumulative PV of $-\$96.35$ is obtained. The calculations for the remaining years of the project are carried out in a similar manner, most conveniently with a spreadsheet. The final NPV at the end of year 2011 is \$25.28 million. Notice that the cumulative PV remains negative until the year 2008. This is equivalent to a payback time of more than 8 yr from the start of plant operation. This is very different from the 2.63-yr payback period computed in Example 17.14, where both the time-value-of-money and the first 2 yr of operation at reduced capacity were ignored.

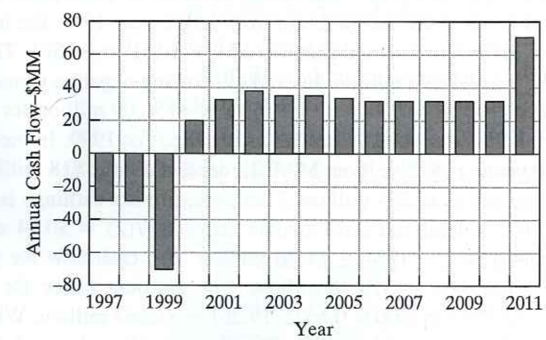
b. The IRR (or DCFRR) is obtained iteratively by conducting the same calculations as in part (a), but with different selected values for the nominal interest rate until an NPV of zero is obtained. Since an interest rate of 15% in part (a) produced a positive NPV, we know that the interest rate for a zero NPV must be greater than 15%. In fact, an IRR of 19% to the nearest integer is obtained.

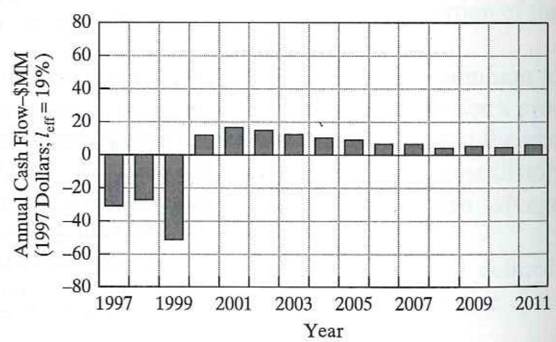
Calculation of Cash Flows (in Millions of Dollars/Year)

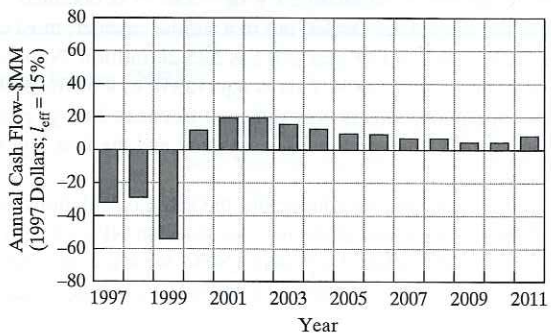
	Investment								
Year	fC_{TDC}	C_{WC}	D	$C_{Excl.\,Dep.}$	S	Net Earn	Cash Flow	Cum. PV @ 15%	IRR
1997	(30.00)						(30.00)	(30.00)	
1998	(30.00)						(30.00)	(56.09)	
1999	(30.00)	(40.00)					(70.00)	(109.02)	
2000			18.00	55.00	75.00	1.26	19.26	(96.35)	
2001			28.80	78.00	113.00	3.91	32.71	(77.65)	
2002			17.28	100.00	150.00	20.61	37.89	(58.81)	
2003			10.37	100.00	150.00	24.97	35.34	(43.53)	
2004			10.37	100.00	150.00	24.97	35.34	(30.25)	
2005			5.18	100.00	150.00	28.23	33.42	(19.32)	
2006				100.00	150.00	31.50	31.50	(10.37)	
2007				100.00	150.00	31.50	31.50	(2.58)	
2008				100.00	150.00	31.50	31.50	4.17	
2009				100.00	150.00	31.50	31.50	10.06	
2010				100.00	150.00	31.50	31.50	15.18	
2011		40.00		100.00	150.00	31.50	71.50	25.28	19%

Net earnings = $(S - C_{Excl.\,Dep.} - D) \times (1.0 - \text{income tax rate})$
Annual cash flow = C = (net earnings + D) $- fC_{TDC} - C_{WC}$

It is of interest to examine the annual cash flows on nondiscounted and discounted bases, as shown in the bar graphs below. The first graph is for the former. For discounted cash flows, the second graph is for an interest rate of 15%, while the third graph is for the IRR of 19%. Note that discounted cash flows during the time of plant operation are much smaller than those for the nondiscounted cash flows in the first graph.







Finally, when calculating annual discounted cash flows, it is not difficult to account for inflation in estimating revenues and costs, when the inflation factors are known. Inflation is considered in the following subsection, but was not included in this example so as to enable the reader to trace the calculations of the cash flows more easily. ■

Inflation

Inflation is the change in the value of a currency over time. Most often, the change is a loss in value. The effect of inflation on a profitability analysis is difficult to include because the future inflation rate is not known and there is no general agreement on how the effect of inflation should be incorporated into present worth calculations. Some argue that revenues and costs increase in the same proportion to the inflation rate factor, making it unnecessary to consider inflation when using a rigorous profitability measure. However, this ignores the fact that depreciation allowances are not adjusted for inflation and, therefore, if revenues and costs increase by the same percentage, the gross earnings increase, making it necessary to pay more income tax, as shown in the following example.

EXAMPLE 17.30

Consider the years 2002 and 2003 of the results in the table of Example 17.29. In 2002 and 2003, income tax in millions of dollars is, respectively,

$$0.37(150.00 - 100.00 - 17.28) = 12.11$$

$$0.37(150.00 - 100.00 - 10.37) = 14.66, \text{ with a cash flow of } 37.89$$

Assume that the results of 2002 are unchanged, but that the sales revenue and production cost, excluding depreciation, both increase by 8% due to inflation. Now the income tax in millions of dollars for 2003 is

$$0.37[150(1.08) - 100(1.08) - 10.37)] = 16.07, \text{ a } 9.6\% \text{ increase in income tax.}$$

The cash flow for 2003 is now 37.93, an increase of about 0.1% over the 37.89 million dollars of the first case of no inflation in 2003. Based on the effect of inflation on the value of currency, the company has fallen behind. Thus, it would appear that it is important to make some correction for inflation, especially if the inflation rate is high. ■

The historic effect of inflation on costs was seen in Chapter 16 in Table 16.6, where four cost indexes and the consumer price index (CPI) were compared. From that table, the following average annual inflation rates, shown in Table 17.11, are obtained for the 10-yr periods of 1980–1990 and 1990–2000. Also included in the table below are the average annual hourly wage increases. In the period of 1980–1990, the average hourly labor wage rate in the United States increased from $6.66 to $10.01, while for 1990–2000 the increase was from $10.01 to $13.67.

The data in Table 17.11 show that recent attempts in the United States to control inflation have met with some success. In the most recent 10-yr period, the cost of chemical plants

Table 17.11 Average Annual Inflation Rates of Cost Indices and Hourly Labor Wages
Rates Are Percent Increase/Year

Period	CE	MS	ENR	CPI	Hourly labor wages
1980–1990	3.21	3.31	3.82	4.72	4.60
1990–2000	0.97	1.67	2.76	2.80	2.80