Calculate Financial Indicators to Guide Investments

John Anderson
Andy Fennell
Dow Chemical

Engineers can become better informed about their work with an increased familiarity of basic financial indicators. Use these insights to help ensure that the projects you work on are those that are most likely to become financial successes.

A key function of chemical engineers is the identification and control of variables that impact the cost of building and operating manufacturing plants. The assessment of the relative value of products and services in the marketplace is another. Thus, it is useful for chemical engineers to understand how combining information from these two activities can yield meaningful insights about the economic viability of products, processes, projects, and, ultimately, businesses. This is particularly true when companies are confronted with a number of investment options; investment in a new product must compete with other opportunities to improve the financial results of an existing business.

Financial indicators can help you choose from a large collection of opportunities to build a solid portfolio of projects that will maximize returns.

This article explains how these key financial indicators are computed and how they can be evaluated and employed. The financial theories on which they are based have been omitted; many resources (*e.g.,* Refs. 1–4) that provide further detail and useful background information on the topic of financial indicators are available.

Study the inputs and their potential variability

Many successful enterprises have been launched by individuals who have no experience with the economic indicators that are presented in business courses and in articles such as this one. This is possible because all financial indicators — and financial success — depend exclusively on the answers to two fundamental questions:

1. How much cash will be earned, and when?
2. How much cash will be spent, and when?

Good business sense can be applied to answer these questions in the absence of any sophisticated evaluation. However, a more-uniform approach is needed when many investment opportunities must be compared objectively.

A research and development organization can (and should) generate more good ideas than its budget can support. Financial studies are useful for paring project lists down to a manageable and profitable portfolio.

Given the nature of R&D, investment decisions must be made when ideas have not been fully developed and both income and expense estimates are uncertain. The estimation of costs in this environment and the means to accommodate uncertainties in either cost or income are discussed in Refs. 5 and 6. When an idea is still new and untested, the value of assessing the impact of all key inputs on these economic indicators cannot be overstated.

Table 1 lists the key questions that R&D personnel must help answer to enable the calculation of financial indicators.

Consider the relative chances for success

All investors understand the balance of risk and reward; clearly, the launch of a brand new product bears more risk than, for example, investment in additional marketing for an existing product or debottlenecking efforts in an operating plant. Methods of quantifying the risk associated with new investments are useful. A company should begin develop-

Table 1. Consider these key R&D inputs when preparing financial analyses of proposed projects.	
Input to Financial Calculations	**Inputs from R&D Required to Ensure Valid Financial Analysis**
Revenue/Market	Is the market new or established? How large is the market? What advantage will the new product/process offer and what is its value? Based on the answers to the two previous questions, what share of the market can be obtained? Are prices for the products well known? Are byproduct credits established? Are byproduct credits vulnerable to changes in demand (such that they could become negative)? Does product demand already exist or will it increase over time? How much time? Will revenues from existing products be affected (portfolio extensions, cannibalization, etc.)? Has the market been assessed in all parts of the world? Are product registrations and/or other regulatory clearances required?
Raw Material Prices	Have suppliers been identified for each of the key raw materials? Are any of the key raw materials available from only one source? Have price quotes/estimates been validated?
Raw Material Usage Rates	Are reaction yields known? How many data points support the assumptions? Is the ability to recycle solvents, catalysts, etc. proven? At what scale have these usage rates been demonstrated? Must operating parameters be tightly controlled to achieve the assumed results? What are the consequences of operating outside the ordinary control limits?
Capital and Conversion Costs	What volume is required by the market? Will the plant be operated at this volume? Will it be operated year-round? Has the process been run in its entirety so that all operations (*e.g.*, waste treatment) are accounted for? Have all unit operations been identified? Is equipment for any unit operation highly specialized or unique? Are the materials of construction requirements well understood? Are all utility requirements known? Are labor rates known? Are labor productivities well understood? Are equipment import restrictions and duties known?
Nonmanufacturing Costs	Will investment be required long before the product is available (*e.g.*, a new plant needs to be built)? How much earlier? What rate of return on loans and/or investments is expected? Is project timing contingent on resource availability? How will timing be affected? Are local tax rates, import duties, etc. that apply to products well known? How long will the product be in demand (*i.e.*, are replacement and/or competitive products being developed)? Does all required infractructure for product transport exist? Is the level of ongoing sales, R&D, and technical support required by the product application(s) well understood?

ing information on risk by collecting historical evidence for projects generated by its R&D function and assessing the success rate of those projects. Note, however, that there is no absolute measure of risk, and consequently no perfect quantification of risk. The academic community has extensively analyzed the interpretation of the riskiness of alternative investments and many textbooks discuss the issue of risk. As time progresses and an idea passes performance, marketing, and cost tests, risk can be considered more formally.

The following sections define the basic financial indicators and how they are calculated. These indicators include: discounted cash flow (DCF), net present value (NPV), internal rate of return (IRR), discounted cash flow percent (DCF%), return on investment (ROI), and payback period.

Discounted cash flow

In simple terms, a net cash flow in any given year is the amount of money remaining after all income has been received and all expenses have been paid. For the highest accuracy, income and expenses should include the impact of taxes, as shown in Examples 1 and 2 later in the article.

To make valid comparisons of projects that start and end at different times, the time value of money must be considered: Money received at some point in the future is worth less than money received at the present time, because money that is received at the present time can be invested to earn a return (*e.g.,* interest on a bank account). The return rate of this alternative investment is known as the opportunity cost of the funds.

Cash flows that occur in the future are therefore discounted to reflect their reduced value at the present time. The rate at which they are discounted is the subject of many volumes, but it should initially reflect the opportunity cost of funds for the investor. This rate is usually a weighted average of the cost of the primary sources of capital, and is commonly referred to as the weighted average cost of capital (WACC). Once the WACC is known, it can be used as a base case for discounting future cash flows.

Several algorithms are available to calculate WACC, but those are beyond the scope of this article. Published tables of discount factors *(4),* and the formulas they are based on, are the foundation for DCF calculations.

Cash flows that occur uniformly over the project life should use a continuous discount rate. Equation 1 is a commonly used formula for continuous discounting:

$$DF_n = \frac{\left(e^r - 1\right) \times \left(e^{-rn}\right)}{r} \qquad (1)$$

where DF_n is the discount factor for cash flow in year n, and r is the discount (or interest) rate. Thus, if the discount rate is 10%, the discount factor that should be applied to a cash flow occurring in Year 5 is 0.6379. A cash flow of \$100 realized five years into the future has a discounted value of \$63.79. This is also known as the present value of that single cash flow.

Net present value

The sum of the discounted cash flows generated in all years that the project is active is called the net present value. The NPV indicates the total cash flow that a project would generate if all revenues and costs associated with the project were reduced to a single instant in time, namely the present. NPV is calculated by:

$$NPV_n = \sum_1^n DCF \qquad (2)$$

where n is the number of periods of evaluation.

The interpretation of an NPV is relatively simple: If NPV > 0, the project will return more than the opportunity cost of funds; if NPV < 0, the project will not return the opportunity cost of funds. When evaluating a portfolio of projects one should choose those that have the highest NPV, based on the same discount rate, term, and risk.

To determine the NPV for any particular project, the lifetime of the project must be specified. Typically, a lifetime of 10, 15, or 20 years is chosen and the corresponding NPV is denoted NPV_{10}, NPV_{15}, or NPV_{20}. The evaluator must be particularly concerned with the selection of the lifetime for projects that may require a prolonged period of development. This is a significant concern for R&D programs; if revenues will not be generated for some years, cash flows will remain negative during that time. In practice, a 10-yr period might not be sufficient for an R&D idea to generate a positive NPV.

It is important to compare project NPVs over the same lifetime. Comparing the NPV_5 of one project to the NPV_{10} of another will be misleading.

The value of an idea depends strongly on how long it can generate positive cash flow. Thus, to make a sound decision about a new product, the time period over which it can remain viable and competitive should be used as the basis of the NPV calculation. Input from both technical and commercial groups may be required to ensure that the financial assessment truly reflects the product's potential.

Since capital is limited and because NPVs are based on assumptions that may prove to be invalid, the manipulation of the discount (or interest) rate can provide additional insights. (Testing the financial robustness of the project by perturbing key input variables is described in Ref. 6.) Increasing the discount rate on risky projects can be useful in setting them apart from less-risky projects, particularly if an objective means of assessing risk can be applied. Clearly, raising the discount rate (opportunity cost) for all projects in a business that has limited capital will reduce the number of them that can return the opportunity cost. This reduces the number of projects that meet the investment criteria and can help match the capital required for the portfolio to the funds that are available.

Internal rate of return and discounted cash flow percent

In Eq. 1, a nominal interest rate, r, must be specified. The equation can be rearranged to compute the value of r for the explicit case where the $NPV = 0$. Conceptually, the NPV is zero if the product breaks even (discounted investment = discounted returns) for a given discount rate. This rate is referred to as the discounted cash flow percent (DCF%) or the internal rate of return (IRR). It can be computed by trial and error, or calculated directly, using a spreadsheet.

The value of the IRR depends on the method used to discount the cash flows. This article uses continuous discount factors in Eq. 1 and the examples. Preprogrammed financial functions available in commercial spreadsheets often employ discrete discounting and, as a result, will yield slightly different results.

Problems with IRR may arise when cash flows fluctuate widely enough to cause the cumulative discounted cash flow (NPV) to move from positive values back to negative values then back to positive again over the term of the project. Such fluctuations are uncommon in a manufacturing or R&D environment, but they do occur occasionally. When this occurs, IRR is not meaningful and other metrics must be used.

Return on investment

Return on investment is often used to justify new investments. ROI is calculated by:

$$ROI = \frac{Profit}{Capital\ Investment} \times 100 \qquad (3)$$

Various definitions of ROI incorporate different meanings of profit and capital investment. Profit may be assessed before or after subtraction of taxes, capital investment may be assessed at different points in the lifetime of the project, and so on. Companies generally specify how these should be calculated. ROI, when applied consistently to a portfolio of projects, is a useful comparison tool.

The ROI value that is considered acceptable to justify an investment also varies. Factors such as the size of a company, the risk associated with the investment, the number and quality of competing opportunities, economic conditions that affect the availability of money, the cost of borrowing, and the industry typically influence the acceptable ROI. Companies often combine these factors with their risk/reward philosophies to specify ROI values that are considered sufficient to justify investment. For example, an ROI of at least 30% might be considered a reasonable first expectation for an investment in products and processes that are still being developed.

Payback period

The time required for a project to return the initial investment is called the payback period. It is computed by calculating the cumulative return for each year and comparing it to the investment; the time at which this sum exceeds the investment is the payback period. Payback period can be calculated using either discounted or undiscounted returns. When undiscounted cash flows are used, the result is called the simple payback period. When discounted cash flows are used, the result is called the discounted payback period.

Payback period (either discounted or simple) is a measure of the return of an investment. It is commonly used on an informal basis to gauge the riskiness of the investment: shorter paybacks enable a business to recover investments with less exposure to risk. Early screening and comparisons using payback period can help a decision-maker form opinions about the portfolio and the relative risks of projects. Although less formal and potentially misleading when used for value maximization, it is nonetheless a commonly used "gut check" indicator.

Interpreting financial indicators

The evaluator needs to consider the conditions that exist when financial indicators are calculated and decisions are made. Often, investment in R&D is required before a commitment can be made to fully commercialize an idea. Money that is invested to enable a well-informed decision (*e.g.,* research to validate a process, produce trial quantities of product, etc.) should not be charged to the project and factored into a decision to proceed (or not) if that money has already been spent at the time the assessment is made, since it cannot be recovered. Costs that have been incurred before the time a decision is made are referred to as sunk costs.

Some R&D projects use idled equipment and other resources that are already on hand. The costs of these should be based on the value of other services that they could be applied to rather than book value, since the equipment has little real value if it is not in use.

The following examples demonstrate the computation of key financial indicators commonly used by businesses to select projects for funding.

In the interest of clarity and brevity, several simplifications have been made. Most projects require capital reinvestment over the course of time, but no allowance is made for that here. Sales and R&D costs incurred both before and during the product's lifetime have also been omitted. Finally, the impact of working capital (*i.e.,* money that must be

	Table 2. Example 1: Financial analysis for a proposed new product launch.										
	A	B	C	D	E	F	G	H	I	J	K
1	Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2	Product Volume, MM lb	—	—	10	15	70	90	100	100	100	100
3	Sales Price, \$/lb	—	—	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
4	Total Revenue, \$MM = Product Volume × Sales Price	—	—	30	45	210	270	300	300	300	300
5	Raw Material Price, \$/lb of product	—	—	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
6	Raw Material Cost, \$MM = Product Volume × Raw Material Price	—	—	20	30	140	180	200	200	200	200
7	Other Costs: Labor, Maintenance, etc., \$MM	—	—	10	11	17	20	21	21	21	21
8	Total Cash Cost, \$MM = Raw Material Cost + Other Costs	—	—	30	41	157	200	221	221	221	221
9	Depreciation, \$MM	—	—	20	20	20	20	20	0	0	0
10	Tax at 30%, \$MM = 0.3 × (Revenue – Cash Costs – Depreciation)	—	—	–6	–5	10	15	18	24	24	24
11	Net Income, \$MM = Revenue – Cash Costs – Depreciation – Taxes	—	—	–14	–11	23	35	41	55	55	55
12	Capital, \$MM	20	80	—	—	—	—	—	—	—	—
13	Cash Flow, \$MM = Revenue – Cash Costs – Taxes – Capital	–20	–80	6	9	43	55	61	55	55	55
14	Discount Factor at r = 10%	0.952	0.861	0.779	0.705	0.638	0.577	0.522	0.473	0.428	0.387
15	Discounted Cash Flow, \$MM = Discount Factor × Cash Flow	–19	–69	5	6	27	32	32	26	24	21
16	NPV_{10}	\$85MM									
17	IRR	23.3%									
18	Steady-State ROI	55%									
19	Payback	~6 years									

spent in advance of revenue generation for the raw materials required for plant startup, building product inventory, etc.) has not been considered.

Example 1: New product launch (Table 2). A new product can be sold at the volumes specified in Row 2 of Table 2 for \$3.00/lb. Raw materials cost \$2.00/lb of product, and other costs are as shown in Row 7. Capital will be invested over a 2-yr period: \$20 million (MM) will be spent in 2013 and the remaining \$80 MM will be spent in 2014 (Row 12).

Cash costs are distinguished from capital depreciation. Depreciation can be considered to be the cost of replacing equipment if the product is expected to be sold for a very long time and replacement equipment or even complete plants will be needed in the future. The funds for these future expenditures should be obtained from the product's sales revenues and are factored into financial calculations as depreciation. Depreciation is not a cash cost that occurs throughout the life of the project; the capital dollars are generally spent before any production or sales can occur. (In this example, the capital spending costs occur in 2013 and 2014.) Rather, depreciation can be included as a cost to reduce the taxes owed on the income from the sale of the product.

In the U.S., the Internal Revenue Service (IRS) establishes rules that govern how much depreciation can be included (*i.e.,* written off) in financial computations in the years after an investment is made. Companies employ experts to ensure that tax relief associated with investment is optimized. For illustration purposes, this example uses a 5-yr, straight-line depreciation schedule: 20% of the initial investment is added as a cost (in Row 9) in each of the five

	Table 3. Example 2: Financial analysis for a hypothetical plant improvement project.										
	A	B	C	D	E	F	G	H	I	J	K
1	Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2	Product Volume, MM lb	—	—	10	10	10	10	10	10	10	10
3	Cost Reduction, $/lb	—	—	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
4	Total Revenue, $MM = Product Volume × Cost Reduction	—	—	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
5	Raw Material Price, $/lb of product	—	—	0	0	0	0	0	0	0	0
6	Raw Material Cost, $MM = Product Volume × Raw Material Price	—	—	0	0	0	0	0	0	0	0
7	Other Costs: Labor, Maintenance, etc., $MM	—	—	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
8	Total Cash Cost, $MM = Raw Material Cost + Other Costs	—	—	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
9	Depreciation, $MM	—	—	1.2	1.2	1.2	1.2	1.2	0	0	0
10	Tax at 30%, $MM = 0.3 × (Revenue – Cash Costs – Depreciation)	—	—	1.0	1.0	1.0	1.0	1.0	1.4	1.4	1.4
11	Net Income, $MM = Revenue – Cash Costs – Depreciation – Taxes	—	—	2.4	2.4	2.4	2.4	2.4	3.2	3.2	3.2
12	Capital, $MM	1.0	5.0	—	—	—	—	—	—	—	—
13	Cash Flow, $MM = Revenue – Cash Costs – Taxes – Capital	–1.0	–5.0	3.6	3.6	3.6	3.6	3.6	3.2	3.2	3.2
14	Discount Factor at r = 10%	0.952	0.861	0.779	0.705	0.638	0.577	0.522	0.473	0.428	0.387
15	Discounted Cash Flow, $MM = Discount Factor × Cash Flow	–0.95	–4.31	2.79	2.52	2.28	2.07	1.87	1.52	1.38	1.25
16	NPV_{10}	$10.4MM									
17	IRR	42%									
18	Steady-State ROI	54%									
19	Payback	~4 years									

years between startup (2015) and 2019.

Annual cash flows were determined by subtracting cash costs and taxes from revenue. Discount factors were calculated by Eq. 1 with an assumed nominal interest rate of 10% and are shown in Row 14 of Table 2. Discounted cash flows were obtained by multiplying the cash flows occurring in each year by the discount factor for that year. The resulting DCFs in Row 15 represent the value today of the money that the product would generate, thereby accounting for the earning potential of money that could be invested now.

The NPV_{10} is the sum of all of the DCFs over a period of 10 years. For this example, NPV_{10} = $85 MM.

The same spreadsheet workbook can be used to compute the IRR, by varying the value of the discount rate (r) until the NPV_{10} is zero. In this example, the IRR was approximately 23%. As noted earlier, the value of IRR is impacted by the discount factors that were computed by Eq. 1. The IRR function in most spreadsheets uses discrete discounting, in which a cash flow's future value changes at discrete intervals (typically 1-yr intervals). Using discrete discounting for this example yields an IRR of 26%. For the purpose of portfolio development, it is most important to ensure that the same discounting method be used for all projects being assessed.

The ROI can be determined at various points in the project's lifetime, and the investor must understand both the definition of ROI that is used and the timeframe to which the calculation applies. In the current example, the project will return 55% of the invested capital each year after sales have grown to their maximum level (in 2020). It is important to note that some time is required before such an ROI is real-

Table 4. This comparison of Examples 1 and 2 shows that although Example 1 generates a higher NPV_{10}, Example 2 requires far less capital expenditures and may be a less-risky project.

Example	Description	NPV_{10}, $MM	Capital Investment, $MM	NPV_{10}/ Capital Investment
1	New Product	$85	$100	0.85
2	Plant Improvement	$10	$6	1.67

ized. Note that the ROI observed in year 2019 is 41%.

The simple payback period can be calculated by adding the undiscounted cash flows (Row 13) and determining when the cumulative income exceeds the investment. The investment is $100 MM. Positive cash flows begin in 2015 (cell D13), two years after the first investment is made in 2013, and after four years exceed the investment amount: $6 MM + $9 MM + $43 MM + $55 MM = $113 MM, which is greater than $100 MM. Thus, the project's simple payback period is approximately six years.

Example 2: Plant improvement project (Table 3). An energy conservation project has been proposed for a small plant that produces 10 MM lb/yr of product. The project would reduce the cost of production by $0.50/lb or $5.0 MM per year (Row 4 of Table 3). (Note that in this example, savings are treated as if they are increased revenue.) New operating costs due to the project's implementation will be $0.4 MM per year (Row 7). The capital cost of the project is $6.0 MM spread over a 2-yr timeframe (Row 12).

The NPV_{10} for this project is $10.4 MM. The IRR based on continuous discount factors is approximately 42%. If discrete discount factors were used, the IRR would be 53%. The ROI in 2022 is 54%, and the simple payback period is about four years.

Discussion. The NPV_{10} for the new product launch (Example 1) is $85 MM, while the NPV_{10} for the plant improvement project (Example 2) is $10 MM. However, the capital required for the new product launch is $100 MM, while the plant improvement project requires $6 MM. When developing a portfolio, it is important to consider the ratio of NPV to capital investment for all projects being considered. Table 4 shows that even though the NPV_{10} of the plant improvement project is lower, its higher NPV-to-capital-investment ratio suggests that it may be a less risky and better overall investment opportunity.

Large DCF and NPV values suggest a high-value project — as in Example 1. It should be noted, however, that multiple small projects are often less risky than a single large project. Therefore, it may be more effective to fund several small projects (like the one in Example 2) instead of one large project. This may be particularly true in cases where the risk factors are related to differing raw material availability, price fluctuations, geographic locations, etc. This phenomenon is the basis of diversification and applies to any portfolio of investments. It is commonly used on portfolios of stocks and bonds, but can be applied equally well to a portfolio of industrial investment opportunities.

Closing thoughts

Multiple small plant-improvement projects may present a company with a better overall investment opportunity than a single new product launch. However, capital costs and financial indicators are not the only criteria on which to base investment decisions. To maximize the value of a project portfolio, these financial indicators must be combined with risk factors, capital availability, and the objectives of the investors. A new product launch, for example, may provide a bigger reward in the long run, in the form of access to new markets, development of other similar products, and diversification of a company's business. CEP

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JOHN ANDERSON works in research and development for Dow Chemical, Core Research and Development (1710 Building, Midland, MI 48674; Phone: (989) 636-8514; Fax: (989) 638-6619; E-mail: jeanderson@dow.com; Website: www.dow.com). An employee of Dow Chemical for 32 years, Anderson has held process engineering, manufacturing and technical service roles. Since 2001, he has been establishing cost and supply information that is used to identify new products and processes with the greatest commercial promise. Anderson received a BS in biology from the Univ. of Michigan-Dearborn in 1979, and an MS in chemical engineering from Wayne State Univ. in 1981.

ANDREW FENNELL currently works as a business analyst in Dow Chemical's Ventures and Business Development organization (2020 W. H. Dow Center, Midland, MI, 48674; Phone: (989) 636-1000). He has worked for Dow developing financial and operational analyses for 29 years, and has worked in many of Dow's functional organizations, including math applications, information technology, treasury, supply chain, controller's, capital planning, economic evaluation, strategic planning, and business analysis. Fennell has also taught collegiate finance courses. He received his BS in business in 1984 and an MBA in 1992, both from Central Michigan Univ. He was Certified in Production and Inventory Management (CPIM) in 2002, and is a Six Sigma Green Belt.