Identifying, justifying and prioritizing technical projects
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Identifying, Justifying and Prioritizing Technical Projects

Improve control for selecting projects for investment and for risk management by following these procedures.

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Not many years ago, managers assigned projects to the technical professionals on their staffs. However, with the extinction of middle-level management, engineers and scientists are now expected to identify, justify and prioritize technical projects of value to the business firm. This article outlines a procedure for identifying, justifying and prioritizing projects of value to the management of a business firm.

To identify projects of value to a firm, it is necessary to understand management's goals *(1)*. One must understand the forces shaping our economy, because it is these forces that determine management's goals. Two forces are shaping today's economy — *globalization* and *demography*.

Globalization is a catch phrase for the transportation revolution combined with the communications revolution. The advent of the turbojet engine reduced the size of the world in terms of travel time. Europe and the U.S. are only five hours apart, while Asia and the U.S. are only separated by 12 to 14 flying hours. The 1973 oil embargo also contributed to the transportation revolution. It led to the development of more-efficient fuel-burning engines and to larger shipping vehicles, in particular, larger aircraft and larger ships. Today, a commercial product can be shipped quickly and cheaply to any part of the world.

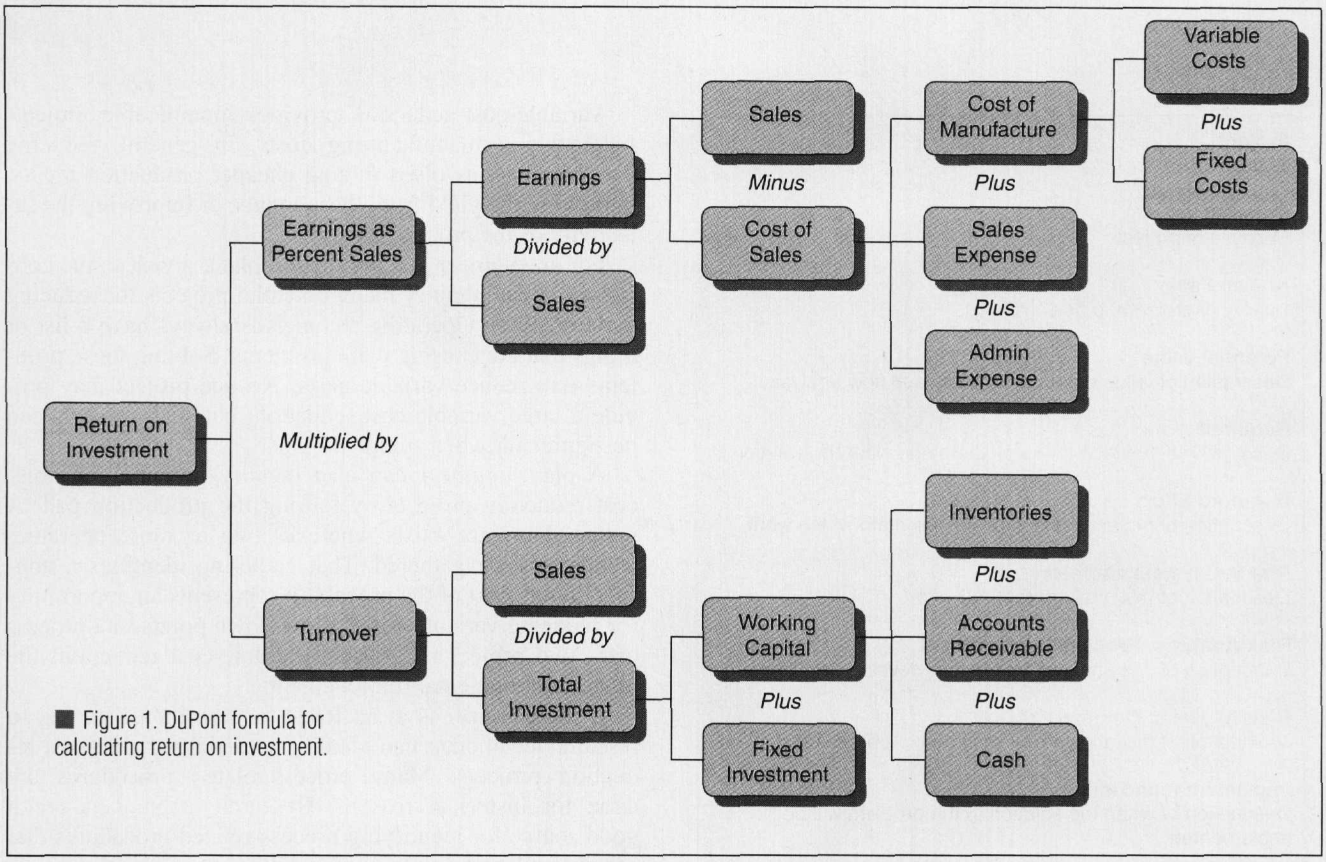
The communications revolution is the other component behind globalization. It began with the invention of the integrated circuit and has accelerated with the formation of the Internet *(2)*. This revolution means we can communicate between locations at nearly the speed of light, and it also means that machine communication can replace non-critical human communication.

Demography is the second force shaping our economy. We use demography as a catch phrase for the financial revolution that started in the mid-1980s. The foundation of this revolution was laid between 1945 and 1955, during the heart of the baby-boom period. At the turn of the 20th century, either families or entrepreneurs owned most firms. However, during the next two decades, the vast majority of these firms were converted to joint-stock corporations in an effort to raise capital for expansion *(3)*.

The rise of the corporation led to the formation and growth of professional managers. During the late 1920s, it became apparent that corporate management existed, to a large extent, independently of corporate ownership. Corporate management became independent of corporate ownership because no one group of stockholders owned enough of the corporation to greatly impact its management.

A debate then developed as to the purpose of such corporations. Should they be managed to optimize their return to society? Should they be managed to optimize their return to their owners? Or, were they being operated to maximize management benefit *(4, 5, 6, 7)*? By the mid-1960s, this debate had narrowed to the latter two questions *(8)*.

The influx of the baby-boom generation into the



■ Figure 1. DuPont formula for calculating return on investment.

workforce and their subsequent investment in pension plans, mutual funds and family-related insurance closed this debate. The dramatic increase in the financial securities held in pension plans, in mutual funds, and by insurance companies provided financial managers with the power to control corporate managers. It only requires the ire of a few financial mangers today to cause a change in corporate management. That change can occur through a sanctioned merger, a hostile takeover, or a vote of "no confidence" at the annual meeting — all orchestrated by a handful of unhappy financial managers. This shift in corporate power constitutes the financial revolution *(9)*. Today, the financial managers holding a company's stock establish its goals.

Return on investment

The financial revolution has reduced the future to the next quarterly financial report. That report indicates whether management is utilizing invested capital to its fullest extent, which will be reflected in increased earnings. With the demise of middle-level management, it is now the technical professional's responsibility to identify and sponsor projects that increase earnings and better utilize invested capital.

In order to identify projects of value, the engineer must know and understand the firm's business strategy. The concept of return on investment (ROI) provides a tool for understanding a company's business strategy *(10)*. ROI was originally developed by DuPont as a means of controlling its middle-level managers, but the engineer can use it to identify projects of potential value to the company *(11)*. There are many schemes for calculating ROI, but the one we will use is the DuPont formula, as shown in Figure 1 *(12)*. We can use this figure to explain the business trends of the past two decades.

There are two ways to better utilize a firm's capital. One is to increase its earnings. The other way is to increase its turnover. We can increase turnover by increasing sales or by reducing total investment. The best way to reduce total investment is to reduce working capital, the sum of inventories, accounts receivable, and cash. Before the 1980s, manufacturers maintained large inventories of production inputs and outputs because a significant amount of any firm's output required rework at any given time. Therefore, to ensure production, a company maintained a significant inventory of production inputs because of the time required to obtain inputs meeting specification. The converse was also true. Firms maintained large product inventories because of the need to ship specification product at any time. Hence, to increase turnover, thereby increasing ROI, meant reducing inventories. It meant instituting "just-in-time" (JIT) delivery of production inputs and outputs. But using JIT means making product right the first time. It means no product reworking; thus the quality revolution of the 1980s was born *(13)*.

Another way of increasing earnings, thereby increasing ROI, is to reduce the cost of sales, the sum of manufacturing costs, sales expenses and administration expenses. The communications revolution has allowed firms to greatly reduce

Project
Title

Concept
Purpose of project

Known Facts
History of problem to be solved.

Potential Value
Description of value determined from cash flow analysis.

Required Work
Description of solution to the problem and what the solution is.

Required Effort
Description of project costs and who will perform the work.

Risk Analysis: Laboratory
Description of risk analysis for R&D effort

Risk Analysis: Process Development
Description of risk analysis for process development effort.

Risk Analysis: Commercial
Description of risk analysis for commercialization effort.

Implementation Timing
Description of when the solution to the problem will be implemented.

Revisions

■ Figure 2. Outline for a typical project summary.

their sales organizations, as well as their purchasing departments. The same is true for administrative expenses; thus, the extinction of middle-level management. Reducing variable costs and fixed costs reduces manufacturing costs. During the 1990s, many manufacturers instituted production teams as a way of reducing fixed costs. These teams became responsible for maintaining and increasing production rate. They were also given the necessary authority to accomplish their goals. They were expected to access the appropriate expert within the firm to help them solve production problems. A major factor in the success of these teams is, again, the communications revolution, which puts them in, essentially, instantaneous contact with all groups within the firm.

Increasing sales also increases earnings. Both the communications and the transportation revolutions have facilitated increased sales. The former allows us to present new products and services to a wider audience through the use of the Internet. The latter allows us to ship product to ever-more-remote markets cheaply and efficiently.

Project identification

Knowing the firm's business strategy and using an ROI scheme similar to Figure 1 provides the means for identifying projects of value to the firm.

Variable-cost reduction provides innumerable projects for reducing manufacturing costs. In general, reducing variable costs involves finding cheaper production inputs, improving the yield from those inputs, or improving the selectivity of the process.

For an engineer at a production plant, a visit to the control room can identify many potential projects for reducing variable costs. Operating technicians always have a list of things that are causing them problems. Solving those problems will reduce variable costs. No one project may provide a large variable-cost reduction, but such projects can be significant when summed.

A plant engineer can also identify potential variable-cost reduction projects by touring the production pad. A potential project exists wherever two or more operating technicians are gathered. That gathering identifies a non-functioning part of the process. It represents an opportunity for reducing variable costs. Blow-down points in a process offer two project types: one, variable-cost reduction; the other, environmental improvement.

If the engineer is at an R&D facility, then listening to research technicians can identify potential variable-cost reduction projects. Many process-related procedures are done for historical reasons. Research technicians are a good source for identifying process-related procedures that require updating.

Analytical chemistry provides another area for project identification. Analytical chemistry takes a quantum step every five years. We should repeat those experiments providing the foundation for our process. One never knows what new peaks will appear. Confirming the assumptions upon which a process is based can provide potential variable-cost reduction projects.

Project justification

Having identified one or more projects, the engineer or scientist must next justify them. Project justification involves analytic skills (economic evaluation) as well as communication skills (presenting information).

Justifying projects begins with a project summary. This organizes the information gathered to date about each project, and it also presents the purpose, history, value and cost of each project. The project summary also contains an analysis of the R&D and process development risks and the commercial risk. The final two categories of a project summary are implementation timing and revision dates. Listing the dates of revision is important because it records the time between project inception and initiation. A particular project may be evaluated and reviewed for several years before it is funded. The project summary also contains appendices. Appendix 1 is an outline, in broad scope, of the project. It will outline the R&D program and/or the process development program. Appendix 2 contains the details of the R&D, process development, and commercial risk analysis. Figure 2 presents an outline for a typical project summary.

Project:	Reduce the amount of Reagent 1 and increase the amount of Reagent 2 used for homogeneous catalyst preparation at the plant.				
Value of Work:	Reduce the cost of homogeneous catalyst preparation.				
Value of Knowledge:	Can be applied to plants in the U.S. and Europe.				
Likelihood of Technical Success:	High.				
Likelihood of Commercial Success:	High.				
Risk:	Low.				
Assumptions:	One person year at R&D facility is $200,000. Project will require one person month at R&D facility; i.e., $12,500. Project will require one person month at plant selected for test; i.e., $12,500. Variable cost reduction is $200,000 per year.				
Calender Year	2000	2001	2002	2003	2004
Project Year	1	2	3	4	5
Capital	$0	$0	$0	$0	$0
Project Expense					
R&D	($12,500)	$0	$0	$0	$0
Plant	$0	($12,500)	$0	$0	$0
Total Cost	($12,500)	($12,500)	$0	$0	$0
Gross Margin from Production					
Income from Variable Cost	$0	$200,000	$200,000	$200,000	$200,000
Income from Fixed Cost	$0	$0	$0	$0	$0
Net Income Before Taxes	$0	$187,500	$200,000	$200,000	$200,000
Depreciation	$0	$0	$0	$0	$0
Taxable Income	($12,500)	$175,000	$200,000	$200,000	$200,000
Income Tax (35%)	($4,375)	$61,250	$70,000	$70,000	$70,000
Net Income After Taxes	($8,125)	$113,750	$130,000	$130,000	$130,000
Cash Flow	($8,125)	$113,750	$130,000	$130,000	$130,000
Discounted Cash Flow (12%)	($8,125)	$101,563	$103,635	$92,531	$82,617
Cumulative Discounted Cash Flow (12%)	($8,125)	$93,438	$197,073	$289,604	$372,221
Earning Power	1413%				
NPV (12%)	$332,341				
PVI	27				
Revisions:	(1) 4 March 1999 (2) 8 September 2000				

■ Figure 3. A sample spreadsheet for cash-flow analysis.

To establish the value of a project, an economic evaluation must be done. A firm's cost of capital, evaluation period, and cost of staff to do an economic evaluation, must be known.

The cost of capital may vary, depending upon the project scale. A company may impose a significantly higher cost of capital for process improvement projects in existing plants than it does for new plant projects. The cost of capital, as determined by the finance department, must be established before starting an economic evaluation.

The interested parties must also agree upon the period of evaluation before starting an economic evaluation. It is difficult to accurately predict financial performance too far into the future, especially if the initial work is done at an R&D facility. Predicting the financial performance of a process improvement at a plant is more accurate. However, the evaluation period for R&D projects and for process improvement projects should be the same as that for projects requiring capital. Because they all compete for the same investment funds, their economic analyses must be comparable.

Finally, an economic evaluation requires an estimate of the cost of doing a project. That cost will include capital, as well as expense items. One expense item that must be determined before starting an economic evaluation is the cost of personnel to work the project.

A cash-flow analysis initiates an economic evaluation. A cash flow analysis is generally done using a spreadsheet program, such as Excel, although a cash-flow diagram can also be used.

The cash-flow analysis is done for a specified evaluation period. A simple cash-flow analysis itemizes required capital, expenses, gross margin, net variable costs, net fixed costs, net income before taxes, and depreciation for the project. The tax rate is also itemized in the cash-flow analysis. The net income after taxes is calculated from this itemized information. The annual cash flow (after taxes) is then calculated. A discounted cash flow and a cumulative discounted cash flow are then calculated from the cash-flow entry.

Various financial measures are calculated from the information itemized in the cash-flow analysis. These financial measures are used to compare and to prioritize the projects. These financial measures constitute an economic evaluation.

The cash-flow analysis should also show the dates of revision with the reason for revision noted. A simple cash-flow analysis using a spreadsheet is shown in Figure 3.

Risk analysis

Risk analysis involves risk identification, risk quantification, risk evaluation and risk acceptance *(14)*. These four activities constitute risk management. Risk identification begins with the outline of the envisioned R&D and/or process development program in Appendix 1 of a project summary. The program outline identifies the sources and nature of the risk associated with each step of the project.

Risk quantification involves assigning a success probability, P(S), to each program step in the project. The impact of failure at each program step must also be estimated. Failure is the opposite of success, and its likelihood is 1 – P(S). Some success probabilities result from objective analysis of the program step, while other success probabilities are subjective, derived from our experience. Each success probability should be fully documented.

Risk evaluation presents the program outline of the project as a decision tree. Using a decision tree allows the engineer to calculate the monetary value of each outcome *(15)*. A decision tree provides the a means for risk management. It clearly shows when a project should be stopped. Figure 4 presents a decision-tree analysis of a typical R&D project.

Risk acceptance occurs when management agrees that the project's benefit to the firm outweighs the risk of losing the initial investment.

Project prioritization

At least once a year, preferably twice, the projects with completed summaries and economic evaluations need to be presented to the firm's management for review and prioritization. The project priority listing generally does not change from one review session to the next, but occasionally a new project is identified with superior attributes, thereby forcing a new prioritization of the project list.

Many methods for prioritizing projects have been developed and published. These prioritization methods can be placed in seven categories — ranking, decision theory, portfolio optimization, simulation (time-dependent portfolio optimization), cognitive modeling, cluster analysis and financial analysis *(16)*. Each category has advantages and disadvantages.

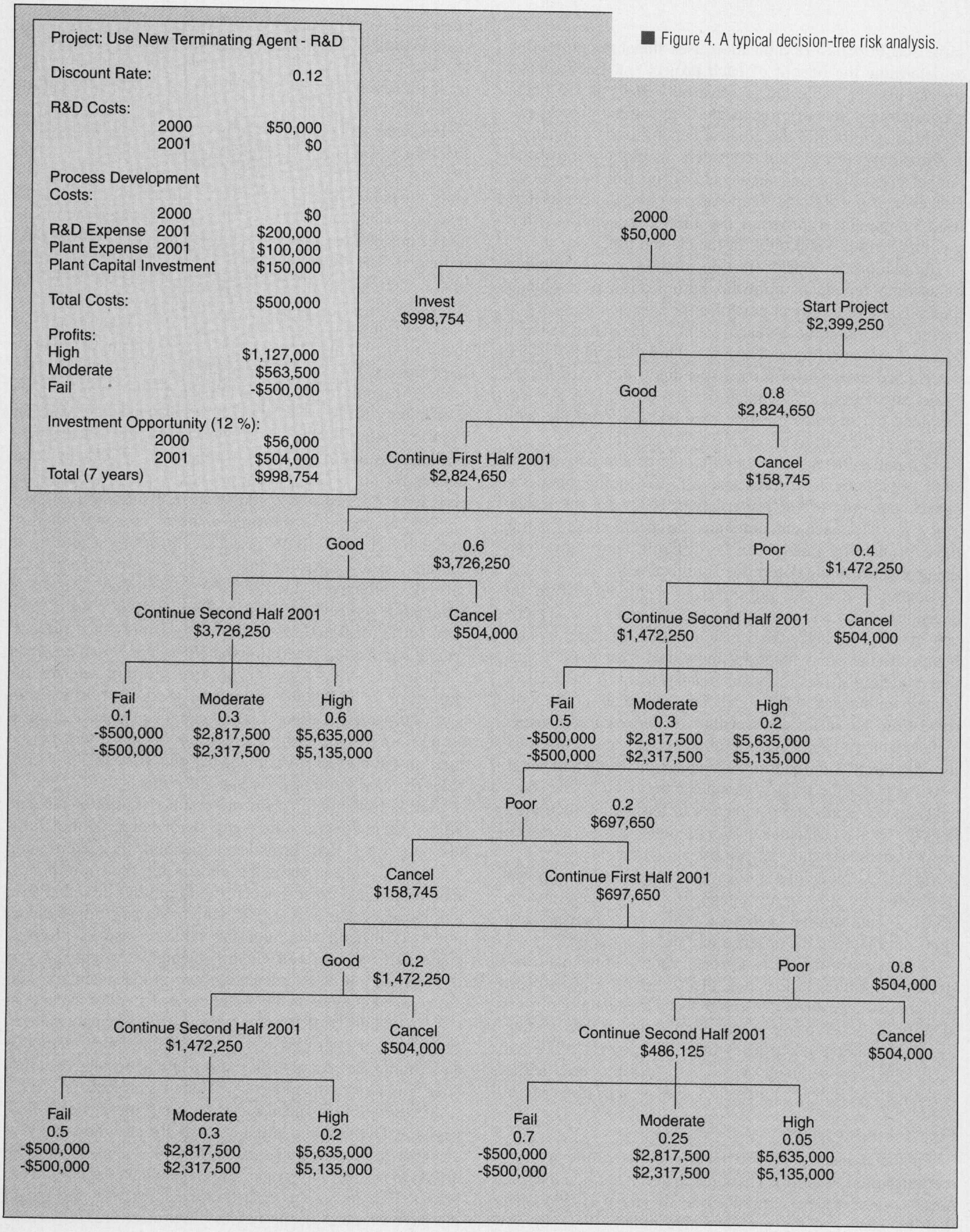
Ranking involves pairwise comparison of every evaluated project. Such a comparison determines which of the two projects is better. More sophisticated ranking procedures involve comparison of two or more criteria. The comparisons are scored using an agreed-upon method. The projects are then ranked from highest to lowest. Projects are funded from the top of the list downward until no more funds are available.

Ranking methods are simple to understand and easy to use. However, such prioritization methods can pick the best of a bad lot and they do no indicate the value of doing one project before any other project. Many times, the scores tend to cluster, making it difficult to rank the projects.

Decision theory provides a method for prioritizing projects that require a series of decisions. In such cases, the outcome of the previous decision intervenes between two successive decisions. Each project is summarized with a decision tree, a display that portrays a series of decisions with outcomes between each successive decision. This method requires an estimate of the likelihood (*i.e.*, probability) of a particular outcome occurring. Decision trees readily show the highest and lowest potential values for each project. The highest potential is then recorded for each project.

Decision theory provides guidance about the appropriate choices to be made at each decision point. However, estimating the probabilities of each outcome is difficult. These probability estimates are generally subjective, since there is little information available for estimating them objectively.

Ranking and decision theory prioritize projects individually. Portfolio optimization prioritizes sets of projects and it establishes the beneficial outcome from the interaction of each project in the set with all the other projects in the



■ Figure 4. A typical decision-tree risk analysis.

same set. Portfolio optimization uses linear programming to determine the benefit of each project set. Each project set can also be subjected to sensitivity analysis via linear programming. Sets of projects are then compared to identify which set provides the greatest benefit to the company.

Portfolio optimization considers resource limitations, budget constraints, and technical and market interactions. However, it is localized temporally — *i.e.*, the parameters used in the linear program are time dependent — thus yielding a result valid only for the chosen time.

Simulation, as a prioritization method, can be thought of as time-dependent portfolio optimization. It evaluates the outcome of a project portfolio for a sequential series of events. The outcome of each event is calculated using a Monte Carlo technique. The most likely outcome is then determined after performing a specified number of Monte Carlo calculations. The spread of each outcome is also determined by this prioritization method. The portfolio with the greatest benefit to the company is then funded.

Simulation determines the outcome of alternative paths each possessing a different payoff, depending upon the chance outcome of each alternative. However, the probability range for each outcome must be specified. Estimating these probability ranges can be difficult, and many times the probabilities are determined subjectively.

Cognitive-modeling prioritization methods analyze the decision process and determine its components. These methods attempt to analyze the decision process of a firm by analyzing the decisions made by individual managers. Cognitive modeling strives to replace management in the decision process with a statistical model. This statistical model is derived from the historical decisions made by each manager. With cognitive modeling, the engineer never discusses the list of projects with the firm's management. Rather, the engineer calculates the various parameters required by the statistical model, inputs the parameters in the model, then tabulates the results of the model. For obvious reasons, managers are not enamored with this prioritization method.

Cognitive modeling studies the entire decision process of a firm, which is an advantage. However, it assumes rational organizational behavior. Cognitive models also choose projects in the absence of a decision maker.

Cluster analysis selects a project set to optimize a firm's strategic position. It does not select a set of projects based on financial measures. Cluster analysis uses dendograms to identify the set of projects best aligned with a firm's strategy. This method identifies groups of projects related to each other by strategy. However, projects are neither ranked nor are financial measures used as selection criteria.

Financial analysis

Financial analysis prioritizes projects according to profit contribution to a firm. This prioritization method uses net present value (NPV), internal rate of return (IRR), cash-flow payback and the present value index (PVI), or any combination of them, as comparison criteria. The projects are listed in order of financial return to the company. Projects are funded from the top of the list downward until no more funds are available.

Financial analysis is deterministic and indicates the value to a firm of each project. However, it uses financial measures that are derived from the cash-flow analysis of the project. Unfortunately, cash-flow analyses require information not readily available. Such analyses contain many assumptions and estimates that can only be substantiated once the project is funded. The need to confirm these assumptions and estimates, then update the cash-flow analysis is another reason for reviewing projects every six months with management.

Most firms use one or more of the measures of financial analysis to prioritize projects. Each of the financial analysis measures has its advantages and disadvantages *(12)*.

NPV assumes the timing and size of the cash flows are predictable. It also assumes that the discount rate (*i.e.*, the required rate of return) is known and valid. If a project's NPV is positive, then its return exceeds the discount rate chosen for the economic evaluation. Thus, only those projects with a positive NPV require prioritization.

NPV accounts for the time value of money as well as variable cash flow. NPV prioritizes projects according to the total value earned during the project's evaluation period. NPV effectively identifies the best project in a set of competing projects. NPV also allows the best set of projects to be identified since the NPV of individual projects can be summed to determine the NPV for a set of projects.

However, NPV does not provide a return rate for the project or an IRR. NPV cannot be used to prioritize projects with greatly different initial capital charges or expenses because it places more emphasis on the return period than on the cost or investment period. NPV does not consider the likelihood of actual results either.

IRR is based on the same assumptions used to calculate NPV, except it does not require knowledge of the firm's discount rate. IRR provides a method for determining whether a project meets the chosen required return rate. IRR prioritizes projects according to return rate rather than a monetary value. Using IRR, which is a percentage value, makes it difficult determine the value of a set of projects, since their individual IRR values cannot be summed.

However, an IRR calculation can produce multiple answers, depending upon the cash flow assumed for the project *(17, 18)*. Multiple IRR values occur most often for uneven cash flows. If cash flow is uneven, then the NPV method is easier to use since it always yields a unique result. Also, IRR does not indicate the monetary value of a project.

The simplest financial measure to calculate is cash-flow payback. Dividing the initial costs by the cash flow per year provides the cash-flow payback. It is the length of time required to recover the project's initial capital charges and expenses. The larger the cash-flow payback (*i.e.*, the longer the payback period), the riskier the project *(12, 19)*. However, the cash-flow payback method neither accounts for the time value of money nor does it credit the income following payoff of the initial costs. In other words, it provides no information about the return rate for the investment made during the project.

PVI involves the same assumptions as those made for NPV. PVI indicates a project's investment utilization. It is the result of dividing the NPV by the present value of the investment. For mutually exclusive projects, PVI is a better financial measure for project prioritization than is NPV *(12)*. However, it does not provide a range of likely results. It also does not indicate the monetary value or the IRR for a project.

No one of the above financial measures is adequate for project prioritization. Most firms use two or more of these financial measures to prioritize projects *(20, 21, 22, 23)*. Since economic evaluations are done using spreadsheets, there is no reason not to calculate all these financial measures, and then use the appropriate ones during project prioritization.

Project review and prioritization meeting

Technical professionals are actually sales people. What they sell is potential — the potential of increased earnings. Potential is the hardest thing to sell. It is intangible, invisible and generally misunderstood.

The project review and prioritization meeting with management is a sales call. The engineer or scientist has two goals for this meeting — first, to obtain management's agreement as to the projects being reviewed, and second, to obtain management's agreement for the presented project prioritization.

To achieve these goals, the engineer or scientist must educate management prior to the meeting. This education occurs by conducting briefings and requesting comments on rough drafts of the project summaries. This provides all those concerned with an opportunity to provide input. This effort should make it possible to conclude the project review and prioritization meeting with agreement as to the technical program for the next six to twelve months. CEP

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