Portfolio Management in New Product Development: Lessons from the Leaders–I

Effective portfolio management, project selection and resource allocation were deemed critical to new product success at 35 companies. However, virtually every company admitted having problems and considered the techniques it was using to be experimental.

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OVERVIEW: *A study of portfolio management practices in industry reveals three goals: maximizing the value of the portfolio, achieving the right balance and mix of projects, and linking the portfolio to the business's strategy. This first of two articles provides examples of portfolio methods used to achieve the first two goals. Maximizing the portfolio's value is achieved by means of various financial models, including the Expected Commercial Value method and the Productivity Index, which are outlined and critiqued. Scoring models are also used to maximize the value of the portfolio. Achieving a balanced portfolio is quite a different issue, involving the use of bubble diagrams and other visual models.*

How can a company most effectively invest its R&D and new product resources? Answering this question is what portfolio management is all about: resource allocation to achieve corporate new product objectives. Much like stock portfolio managers, those senior managers who succeed at optimizing their R&D investments—who define the right new-product strategy for their firm, select the winning new-product projects, and achieve the ideal balance of projects—will win in the long run.

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This article reports the results of an exploratory investigation into portfolio management practices (see "How the Study Was Done," next page). It tells how leading firms manage their R&D portfolios, and offers insights and recommendations to help your company achieve a greater return from its R&D investment (*1*).

Understanding Portfolio Management

Portfolio management and the prioritization of new product projects is a critical management task. Roussel, Saad and Erikson in their widely-read book claim that ". . . new product portfolio analysis and planning will grow in the 1990s to become the powerful tool that business portfolio planning became in the 1970s and 1980s" (*2*).

Portfolio management and project prioritization is about resource allocation in the firm; that is, which new-product projects shall the corporation fund from the many opportunities it faces? And, which ones shall receive top priority and be accelerated to market? It is also about corporate strategy, because today's new-product projects decide tomorrow's product/market profile of the firm. An estimated 50 percent of firms' sales today come from new products introduced within the last five years (*3,4*). Finally, it is about balance; namely, the optimal investment mix between risk versus return, maintenance versus growth, and short-term versus long-term new product projects.

We define portfolio management as a dynamic decision process, whereby a business's list of active new product (and R&D) projects is constantly updated and revised. In this process, new projects are evaluated, selected and prioritized; existing projects may be accelerated, killed or de-prioritized; and resources are allocated and reallocated to the active projects.

The portfolio decision process is characterized by uncertain and changing information, dynamic opportunities, multiple goals and strategic considerations, interdependence among projects, and multiple decision makers and locations. The process encompasses or overlaps a number of decision-making processes within the business, including periodic reviews of the total portfolio of all projects (looking at the entire set of projects, all projects against each other), making Go/Kill decisions on individual projects on an on-going basis, and developing a new product strategy for the business, complete with strategic resource allocation decisions.

New product portfolio management sounds like a mechanistic exercise of decision making and resource allocation. But there are many unique facets of the problem that make it perhaps the most challenging decision-making faced by the modern business. First, new-product portfolio management deals with *future events* and opportunities; thus, much of the information required to make project selection decisions is at best, uncertain, and at worst, highly unreliable. Second, the decision environment is a *dynamic* one; the status and prospects for projects in the portfolio are continually changing as new information becomes available. Next, projects in the portfolio are at *different stages* of completion, yet all projects compete against each other for resources; consequently, comparisons must be made between projects with different amounts and "goodness" of information. Finally, *resources* to be allocated across projects are limited; a decision to fund one project may require taking resources away from another, and resource transfers between projects are not totally seamless.

The challenge of portfolio management in product development is not new. Over the decades, the topic has surfaced under various guises including "R&D project selection", "R&D resource allocation", "project prioritization," and "portfolio management". By the early 1970s, dozens of articles had appeared on the topic, with most authors only making one stab at it before moving on to more fruitful fields.

The majority of these early proposed methods were management science optimization techniques. To the management scientist, this portfolio management problem is one of constrained optimization under conditions of uncertainty: a multi-project, multi-stage decision model solved by mathematical programming. The original portfolio selection models were thus highly mathematical, and employed techniques such as linear, dynamic and integer programming. The objective was to develop a portfolio of new and existing projects to maximize some objective function (for example, the expected profits), subject to a set of resource constraints.

Anyone familiar with these programming techniques will immediately recognize the hurdles that the mathematician and management scientist would face in solving this portfolio problem. Further, despite the many methods proposed in the early days, there was a remarkable lack of follow-up; few authors ever described attempts to actually implement their methods and to gauge their feasibility. Indeed, the articles in the 1960s and 1970s appear to be largely the result of academics writing to and for one another. In spite of the importance of the topic, no guru or "dominant school of thought" ever emerged here, perhaps an indication of the frustrations encountered when seeking solutions (*5–9*).

Portfolio Methods in Practice

How are leading firms handling portfolio management? Here we outline the portfolio methods used by a selection of companies known to be actively using or developing and implementing a portfolio management process. Before we delve into the details of these processes, consider some of the study's key findings which became evident immediately:

First, every company we interviewed believed the portfolio management, project selection and resource allocation problem to be critical to new product success.

How the Study Was Done

Interviews were conducted in 35 leading firms in various industries. Five companies were singled out for in-depth and detailed interviews, on the basis of the uniqueness and proficiency of their portfolio approach. The companies, although quite willing to share the details of the portfolio approaches with us, were promised anonymity in some cases. Also, in no way do we reveal any details on any project under development—all illustrations use disguised projects. These leading firms included:

- The U.S. arm of the world's largest chemical company (Hoechst).
- A major industrial materials supplier—the number one in its industry in the world (English China Clay).
- A major high-technology materials producer.
- A major financial institution (Royal Bank of Canada), among the top five in North America.
- A multinational consumer goods company (Reckitt & Colman, U.K.).

Three of the five were in the United States. Additionally, another 30 companies provided data on their portfolio methods, experiences and outcomes (most were from North America). Note that the method of sample selection was purposeful (not random); we deliberately selected firms according to their experience, proficiency and ability to provide insights regarding portfolio management. During the interviews, the details of the portfolio approaches used, the rationale, problems faced and issues raised were all investigated (*1*).

The study is a two-part study: Phase 1 has been completed and is reported here; Phase II is underway in cooperation with the Industrial Research Institute, and involves a much larger sample size.—**R.G.C., S.J.E. and E.J.K.**

However, virtually all companies had experienced problems with project selection. And with resources tighter than ever, the issue of proper resource allocation and picking the right projects was paramount. Further, the desire to see the business's strategy reflected in its portfolio of R&D investments was another driver of improved portfolio management techniques.

Second, the problems the companies faced in project selection and portfolio management that were creating the sense of urgency for better portfolio management are familiar ones:

■ *Does not reflect strategy*—Many businesses or SBUs studied had enunciated business strategies; in some cases, they even had developed new product strategies for the business. These strategies defined the goals for new products (e.g., by year five, 32 percent of sales revenue will be generated by products we do not now have), the role that product development will play in achieving overall business goals, and even strategic arenas of focus—which product types, markets and technologies (or platforms) will generate these new products. The problem lay in linking these strategies—business and new product—to spending on R&D projects. A breakdown of R&D spending by project types often revealed serious disconnects between goals/strategies of the business and where the money was spent.

■ *Poor quality portfolios*—Managers were generally displeased with, or at best doubtful about, their firm's current portfolio of projects. Many new-product projects were thought to be weak or mediocre; others were considered unfit for commercialization; and success rates in the marketplace were less than adequate. As one manager put it: "We implemented our portfolio management approach [a risk/reward bubble diagram], and the first thing that became evident was that half our projects were in the wrong quadrants, including some of our big ones! By the end of the year, the list of projects had been cut in half." Similar audits had resulted in similar cuts in other firms, leading one to doubt the quality of current portfolios.

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■ *Tunnels, not funnels*—A related problem is that Go/Kill decision points—the gates in new product processes—were often perceived to be ineffective. In too many companies, projects tended to get a life of their own, and little could stop them once they gained momentum. In one large consumer firm, an internal audit of 60 current projects revealed that 88 percent resembled an express train . . . "slowing down at stations [project reviews], but never with the intention of being stopped!" Only 12 percent were handled thoughtfully with rigorous Go/Kill decision points. Even when killed, the complaint in some firms was that projects had a habit of being resurrected, perhaps under a new name.

■ We observed that criteria for making Go/Kill decisions were inadequate or not used, and that often a mechanism for rating, prioritizing or even killing projects was lacking. As one frustrated manager exclaimed: "We talk about having a funnelling process that weeds out poor projects; heck, we don't have a funnel—we have a tunnel . . . ten projects enter the process, ten go into Development, ten go to Launch . . . and one succeeds!"

■ *Scarce resources, a lack of focus*—Resources are too scarce to waste on the wrong projects. Indeed, a common complaint was that product development was suffering from too-lean resources, especially in marketing and manufacturing/operations. Most firms confessed to having far too many projects for the limited resources

Key Problems in Portfolio Management and Project Selection

Portfolio management, project selection and resource allocation were deemed critical to new product success by all firms in the study. But every firm faced problems in this respect:

1. The portfolio of projects does not reflect the business's strategy: Too many projects are "off strategy," and there are disconnects between spending breakdowns on projects and the strategic priorities of the business.

2. The portfolio's quality is poor: There are too many unfit, weak and mediocre projects; success rates at launch are inadequate.

3. Firms' new product processes are *tunnels* when they should be *funnels*. The Go/Kill decision points are weak; projects tend to take on a life of their own; poor projects are often not killed.

4. Resources are scarce, and there is a lack of focus: Most firms confess to having far too many projects for the limited resources available; cycle times and success rates are suffering as a result.

5. Some firms admitted to having too many trivial projects in their new product pipeline—modifications, up-dates and extensions—and too few of the projects needed to yield major breakthroughs and real competitive advantage. This is the result of the quest for cycle time reductions, coupled with insufficient resources.

available. The result was that resources were spread very thinly across new-product projects, so that even the best projects were starved for people, time and money. As a result, projects were taking too long to reach the market, and such key activities as up-front homework, getting sharp, early product definition, and building in the voice of the customer were not being executed as well or consistently as they should be.

■ *Trivialization of product development*—The quest for cycle-time reduction, together with the desire for more new products than ever, when coupled with resource constraints, led many firms to do the obvious: pick "low hanging fruit"—projects that could be done quickly, easily and cheaply. Often these projects were trivial ones—modifications, extensions and up-dates—while the significant products, which were the ones needed to yield real competitive advantage and major breakthroughs, were often placed on the back burner. The result was a portfolio of short-term projects, with projects designed to create tomorrow's big winners, such as technology platforms, missing.

Many of the portfolio techniques presented below are new to the companies involved. For example, a major consumer goods company and a materials firm had set up task forces to deal with the portfolio problem one year before our interviews and were only in the early stages of implementation at the time of the interviews. We saw new, relatively untried methodologies being implemented in other firms as well. Thus, the reader should treat some of the techniques described as "exploratory" and "experimental" rather than tried-and-proven methods.

Portfolio Management Goals

While the portfolio methods employed in these firms varied greatly, the common denominator across firms was the *goals* management was trying to achieve. One or more of three high-level or macro goals dominated the thinking of each firm we studied, either implicitly or explicitly. Which goal was most emphasized by the firm in turn seemed to influence the choice of portfolio method. These three broad or macro goals were:

■ *Value Maximization*—In some firms, the preoccupation was to allocate resources so as to maximize the value of the portfolio in terms of some company objective (such as long-term profitability, return-on-investment, likelihood of success, or some other strategic objective).

■ *Balance*—Here the principal concern was to achieve a balance of projects in terms of a number of parameters; for example, the right balance of long-term projects versus short ones; or high-risk versus lower-risk, sure bets; and across various markets, technologies, product categories, and project types (e.g., new products, improvements, cost reductions, maintenance and fixes, and fundamental research) (*10*).

One or more of three high-level goals dominated the thinking of each firm we studied, either implicitly or explicitly.

■ *Strategic Direction*—The main focus here was to ensure that, regardless of all other considerations, the final portfolio of projects truly reflected the business's strategy—that the breakdown of spending across projects, areas, markets, etc., was directly tied to the business strategy (e.g., to previously delineated areas of strategic focus), and that all projects were "on strategy."

What becomes clear is the potential for conflict between these three high-level goals. For example, the portfolio that yields the greatest NPV or IRR may not be a balanced one (it might contain a majority of short-term, low-risk projects, or be overly focused on one market). Similarly, a portfolio that is primarily strategic may sacrifice other goals (such as short-term profitability).

Our interviews also revealed that although managers did not explicitly state that one of the above goals took precedence over the other two, the nature of the portfolio management tool elected by that firm certainly indicated a hierarchy of goals. This was because certain portfolio approaches were more applicable to some goals than others; for example, the visual models (such as portfolio bubble diagrams) were most amenable to achieving a balance of projects (visual charts being an excellent way of demonstrating balance), whereas scoring models tended to be very poor for achieving or even showing balance but most effective if the goal was maximization against an objective. Thus, the choice of the "right" portfolio approach depends on which goal management explicitly or implicitly focuses on.

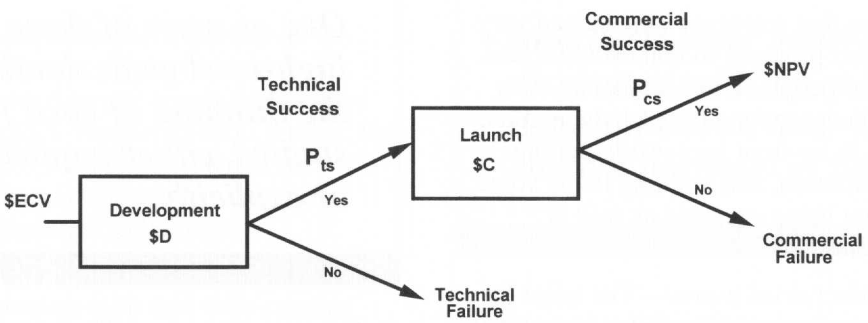
Which methods did firms find most effective for achieving the three portfolio goals? The next sections outline the methods, complete with strengths and weaknesses, beginning with the goal of maximizing portfolio value.

Maximizing the Value of the Portfolio

A variety of methods were used to achieve this goal, ranging from financial models to scoring models. Each has its strengths and weaknesses. The end result of each method is a rank-ordered list of "Go" and "Hold" projects, with those at the top scoring highest in terms of achieving the desired objective(s); the value in terms of that objective is thus maximized.

Expected Commercial Value

This method seeks to maximize the "value" or *commercial worth* of the portfolio, subject to certain budget constraints.



$$ECV = [(NPV * P_{cs} * SI - C) * P_{ts} - D]$$

$ECV = Expected Commercial Value of the project
SI = Strategic Importance of Project (a 1,2,3 score)
P_{cs} = Probability of Technical Success
P_{ts} = Probability of Commercial Success (given technical success)
$D = Development Costs remaining in the project
$C = Commercialization (launch & capital) Costs
$NPV = Net Present Value of project's future earnings (discounted to today)

Figure 1.—English China Clay Co. determines a project's expected commercial value (EVC) from this decision tree analysis.

It is one of the better-thought-out financial models, featuring several new twists that make it particularly appropriate to portfolio management. We found it in use at English China Clay (ECC), a major materials producer with U.S. headquarters in Atlanta, Georgia.

The ECV method determines the commercial worth of each project to the corporation; namely, its *expected commercial value.* This calculation, shown in Figure 1, is based on a decision tree analysis, and considers the future stream of earnings from the project, the probabilities of both commercial success and technical success, along with both commercialization costs and development costs. It also incorporates the strategic importance of the project.

In order to arrive at a prioritized list of projects, ECC considers scarce resources. In ECC's case, capital resources are thought to be the constraining or scarce resource (note that many of ECC's projects are very capital-intensive). Other companies may choose to use R&D people or work-months, or R&D dollars, as the constraining resource. ECC takes the ratio of what it is trying to maximize—namely the ECV—divided by the constraining resource, namely the capital cost per project. Projects are rank-ordered according to this ratio, thereby ensuring the greatest "bang for buck"; that is, the ECV is maximized, for a given capital budget (*11*).

This ECV model has a number of attractive features. Because it is based on a decision tree approach, it recognizes that if the project is halted partway through, certain expenses are not incurred, and that the Go/Kill decision process is a step-wise or incremental one. (For example, the simplistic route adopted by some—namely, multiplying the NPV of a project by its probability of success—fails to capture this subtlety). A second feature is that all dollar amounts are discounted to today (not just to the launch date), thereby appropriately penalizing projects that are years away from launch. A third benefit is that the ECV, although largely financially-based, does consider the strategic importance of projects. Finally, the model recognizes the issue of constrained resources and attempts to maximize in light of this constraint; in other words, it strives for "maximum bang for buck" rather than just "maximum bang."

The major weakness of the method is the dependence on financial and other quantitative data. Accurate estimates on *all* projects' future stream of earnings, on their commercialization (and capital) expenditures, on their development costs, and on probabilities of success are model inputs—estimates that are often unreliable, or at best, simply not available early in the life of a project. For example, one seasoned executive took great exception to multiplying two very uncertain probability figures together: "This will always unfairly punish the more venturesome projects!"

A second weakness is that the method does not look at the balance of the portfolio—at whether the portfolio has the right balance between high-and low-risk projects, or across markets and technologies. A third weakness is that the method considers only a *single criterion*—the ECV—for maximization (although admittedly, this ECV is composed of a number of parameters).

Productivity Index

The PI is similar to the ECV method described above, and shares many of its strengths and weaknesses: the PI also tries to maximize the financial value of the portfolio for a given resource constraint. We saw the method in use in two firms: a medical products firm in the U.S. and a nuclear firm in the U.K. The method is one advocated by the Strategic Decisions Group (*12*).

The Productivity Index = $[ECV * P_{ts} - \text{R\&D}]/R\&D$

Here, *expected commercial value* (*ECV*) is a probability-weighted stream of cash flows from the project, discounted to the present, and assuming technical success. Note that the definition of *ECV* here is different from that used by English China Clay (Figure 1). P_{ts} is the probability of technical success, while *R&D* is the R&D expenditure remaining in the project (R&D monies already spent on the project are sunk costs and hence not relevant to the decision). Projects are rank-ordered according to this index in order to arrive at the preferred portfolio.

Dynamic Rank Ordered List

The next method overcomes the limitation of relying on only a single criterion to rank projects, such as ECV or PI shown above. We call it the Dynamic Rank Ordered List approach, although Company G, a telecommunications hardware supplier, simply called it their "portfolio model." This method has the advantage that it can rank-order according to several criteria concurrently, without becoming as complex and time-consuming as the use of a full-fledged, multiple-criteria scoring model. These criteria can include, for example: profitability and return measures, strategic importance, ease and speed to do, and other desirable characteristics of a high-priority project. The four criteria used by Company G are (see Table 1):

- *Strategic importance* of the project; namely, how important and how aligned the project is with the business's strategy. It is gauged on a 1–5 scale, where 5 = critically important.

- *NPV* (net present value) of the future earnings of projects, less all expenditures remaining to be spent on the project. Here, the NPV has built into it probabilities

Hoechst-U.S. had constructed one of the best scoring models we have seen.

of commercial success. (In calculating the NPV, sales revenues, margins, etc. have all been multipled by probabilities to account for uncertainties.) NPV was considered to be an important criterion because it captures the "bang" or financial impact of projects.

- *IRR* (internal rate of return), calculated using the same data as the NPV, gives the percent return. Management here considered IRR also to be important, capturing "bang for buck."

- *Probability of technical success* as a percentage. Some projects were very speculative technically.

How are projects prioritized or ranked on four criteria simultaneously? Simple: First, the probability of technical success is multipled by each of the IRR and NPV to yield an adjusted IRR and NPV. Next, projects are ranked independently on each criterion: adjusted IRR, adjusted NPV, and strategic importance (see numbers in parentheses in Table 1). The final, overall ranking—the far right column in Table 1—is determined by calculating the mean of the three rankings. For example, Project Alpha scored first on strategic importance and second on each of IRR and NPV; the mean of these three rankings is 1.67, which places Alpha at the top of the list. Simple perhaps, but consider the list of projects in Table 1 and try to arrive at a better ranking yourself—one that maximizes against all three criteria!

The major strength of this dynamic list is its simplicity: Rank-order your projects on each of several criteria and take the mean of the rankings! Another strength is that the model can handle several criteria concurrently, without becoming overly complex. Its major weakness is that the model does not consider constrained resources (as did the ECV or PI methods above, although

Table 1—Dynamic Rank-Ordered List, as Used by Company G

Project	IRR*PTS	NPV*PTS	Strategic Importance	Ranking Score*
Alpha	16.0 (2)	8.0 (2)	5 (1)	1.67 (1)
Epsilon	10.8 (4)	18.0 (1)	4 (2)	2.33 (2)
Delta	11.1 (3)	7.8 (3)	2 (4)	3.33 (3)
Omega	18.7 (3)	5.1 (4)	1 (6)	3.67 (4)
Gamma	9.0 (6)	4.5 (5)	3 (3)	4.67 (5)
Beta	10.5 (5)	1.4 (6)	2 (4)	5.00 (6)

Notes: Both IRR and NPV are multiplied by Probability of Technical Success. Projects are then ranked according to the three criteria; numbers in parentheses show the ranking in each column. Projects are rank-ordered until there are no more resources.
*The final column is the mean across these three rankings. This is the score on which the six projects are finally ranked. Project Alpha is number 1; Project Beta is last.

conceivably Company G could build this into its rank-ordering model), and like the ECV and PI models, it is largely based on uncertain, often unreliable, financial data. Finally, it fails to consider the balance of projects.

Scoring models

Scoring models have long been used to make Go/Kill decisions at individual project reviews or gates, but they are also applicable to project prioritization and portfolio management. Here, a list of criteria is developed to rate projects—criteria believed to discriminate between high- and low-priority projects. Projects are then rated by evaluators on each criterion, typically on 1–5 or 0–10 scales with anchor phrases. Next, these scores are multiplied by weightings, and summed across all criteria to yield a *project score* for each project.

Although many firms we interviewed professed to use such scoring models, either they were poorly crafted models (for example, inappropriate criteria), or there were serious problems in the actual use of the model at management decision meetings. Consequently, such models often fell into disuse. The key seemed to be the construction of an appropriate list of scoring criteria—ones that really do separate winners from losers—and a procedure to gather the data and use the model at a management meeting.

Hoechst–U.S. had constructed one of the best scoring models we have seen. It took several years of refinement, but the eventual model is so well-conceived that we report it here. Each question or criterion (Table 2) had been carefully selected and worded, operationally defined, and tested for validity and reliability over some years.

The five major factors considered in prioritizing Hoechst's projects are:

- Reward (to the company).
- Business strategy fit (fit with the business unit's strategy).
- Strategic leverage (ability of the project to leverage company resources and skills).
- Probability of commercial success.
- Probability of technical success.

Within each of these five factors are a number of specific characteristics or measures (19 in total), which are scored on 1–10 scales by management. The 19 scales are anchored (scale points 1, 4, 7, and 10 are defined) to facilitate discussion. Simple addition of the items within each factor yields the five factor scores, which are added together in a weighted fashion to yield an overall program attractiveness score for the project. This final score is used for two purposes:

1. *Go/Kill decisions at gates*—The program attractiveness score is one input to the Go/Kill decisions made by senior management at each gate in Hoechst's Stage–Gate^{tm} new product process; a score of 50 percent of maximum is the cut-off or hurdle.

2. *Prioritization*—Immediately following the gate meeting, a portfolio review occurs, prioritization of "Go" projects from the gate takes place, and resources may be allocated to the approved projects. Here, the program attractiveness scores for the new projects are compared to

Table 2—Hoechst's 19-Question Scoring Model

Reward
- Absolute contribution to profitability (5-year cash flow: cumulative cash flows less all cash costs, before interest and taxes).
- Technological payback: the number of years for the cumulative cash flow to equal all cash costs expended prior to the start-up date.
- Time to commercial start-up.

Business Strategy Fit
- Congruence: how well the program fits with the strategy (stated or implied) for the product line, business and/or company
- Impact: the financial and strategic impact of the program on the product line, business and/or company (scored from "minimal" to "critical").

Strategic Leverage
- Proprietary position.
- Platform for growth (from "one of a kind" to "opens up new technical and commercial fields").
- Durability: the life of the product in the marketplace (years).
- Synergy with other operations/businesses within the corporation.

Probability of Commercial Success
- Existence of a market need.
- Market maturity (from "declining" to "rapid growth").
- Competitive intensity: how tough or intense the competition is.
- Existence of commercial application development skills from "new" to "already in place").
- Commercial assumptions (from "low probability" to "highly predictable").
- Regulatory/social/political impact (from "negative" to "positive").

Probability of Technical Success
- Technical gap (from "large gap" to "incremental improvement").
- Program complexity.
- Existence of technological skill base (from "new to us" to "widely practiced in company").
- Availability of people and facilities (from "must hire/build" to "immediately available").

Each criterion (question) is scored 1–10; 1, 4, 7, and 10 are "anchored."
The five factors are calculated via weightings × ratings, and added in a weighted fashion to yield a project score.
Projects are ranked by project score until there are no more resources!

the scores of active projects (previously resourced) in order to determine the relative prioritization of the new projects.

Managers at Hoechst and other firms were generally pleased with scoring models, but all confessed that some rough edges remained to be ironed out:

- *Imaginary precision:* Using a scoring model imputed a degree of precision that simply did not exist; as one Hoechst executive exclaimed, "They're trying to measure a [soft] banana with a micrometer!"

- *Halo effect:* This was a concern at the Royal Bank of Canada (RBC), which over the years had cut its list of multiple criteria in its scoring model down to five key criteria. Why? Management argued that if a project scores high on one criterion, it tends to score high on many of the rest—a halo effect.

- *Efficiency of allocation of scarce resources:* Missing from the scoring models was a means of ensuring that the resulting list of Go projects actually achieved the highest possible score for a given total R&D expenditure. For example, an artifact of one firm's scoring model was that much larger projects tended to rise to the top of the list; however, if the ranking criterion had been "Project Score/R&D Spend" instead of just "Project Score," then some smaller but efficient projects—ones that required; less R&D resources—would have risen to the top.

Greatest Weakness

Although the value maximization methods outlined above have much to commend them, their greatest weakness as a group is that they fail to ensure that the portfolio is strategically aligned and optimally balanced. For example, the resulting portfolio of projects generated via any of the above methods might maximize profits or some project score, but yield an unbalanced list of projects (for example, too many short-term ones) or fail to mirror the strategic direction of the business. These goals—balance and strategic alignment—are discussed below.

In spite of these weaknesses, maximization of the portfolio's value is still a worthwhile objective. We can argue about balance, and philosophize about strategic direction of the portfolio, but if the projects in the portfolio are poor ones—poor profitability, low likelihood of success or poor attractiveness scores—then the portfolio exercise is academic. First and foremost, a portfolio must contain "good" projects, and that is where the maximization methods outlined above excel. One cannot ignore these methods; they must be part of your portfolio-building repertoire.

A Balanced Portfolio

The second major goal sought by some firms is a balanced portfolio—a balanced set of development projects in terms of a number of key parameters. The analogy is an investment fund, where the fund manager seeks balance in terms of high-risk versus blue-chip stocks, domestic versus foreign investments, and balance across industries, in order to arrive at an optimum investment portfolio.

Visual charts were favored for displaying balance in new-product project portfolios. These visual representations include the portfolio maps or bubble diagrams (Figure 2) which are an adaptation of the four-quadrant BCG (star, cash cow, dog, wildcat) diagrams, as well as more traditional pie charts and histograms.

A casual review of portfolio bubble diagrams will lead some to conclude that these new models are nothing more than the old strategy bubble diagrams of the '70s! *Not so.* Recall that the BCG strategy model, and others like it (such as the McKinsey/GE model), plotted SBUs on a market attractiveness versus business position grid. The key here is that the unit of analysis was the SBU—an existing business, and whose performance, strengths and weaknesses are all known. By contrast, although today's new-product portfolio bubble diagrams may appear similar, they plot individual new-product projects—future businesses, or *what might be* as opposed to *what is.* As for the dimensions of the grid, there too the "market attractiveness versus business position" dimensions used for existing SBUs may not be appropriate for new products; consequently, we saw other dimensions or axes being used extensively.

Dimensions To Consider

Which parameters do companies plot on these bubble diagrams in order to achieve balance? Pundits recommend various parameters and lists, and even suggest the "best plots" to use. Here is a sample list of possible parameters to consider; any pair can be the X and Y-axes for a bubble plot (*2*):

- Fit with business or corporate strategy.
- Inventive merit and strategic importance to the business.
- Durability of the competitive advantage.
- Reward, based on financial expectations.
- Competitive impact of technologies (base, key, pacing, and embryonic technologies).
- Probabilities of success (technical and commercial success).
- R&D costs to completion.
- Time to completion.
- Capital and marketing investment required to exploit.

Risk–Reward Bubble Diagrams

Perhaps the most popular bubble diagram is a variant of the *risk/return diagram.* Here, one axis is some measure of the reward to the company; the other is a success probability:

■ Some firms use a *qualitative estimate* of reward, ranging from "modest" to "excellent" (*2*). Management points out that too heavy an emphasis on financial analysis can do serious damage, notably in the early stages of a project. The other axis is the probability of overall success (probability of *commercial* success multiplied by probability of *technical* success).

■ In contrast, other firms rely on quantitative and financial gauges of reward; namely, the risk-adjusted NPV of the project (*13,14*). The NPV is adjusted for risk by means of a risk-adjusted discount rate to determine the NPV, applying probabilities to uncertain estimates in calculating the NPV, or via Monte Carlo simulation to determine NPV. The probability of *technical* success is the vertical axis, as probability of commercial success has already been built into the NPV calculation.

Figure 2 shows a bubble diagram for a division of a major chemical company, Company T. The size of each bubble shows the annual resources spent on each project (in Company T's case, this is dollars per year; it could also be people or work-months allocated to the project).

The four quadrants of the portfolio model are:

• *Pearls* (upper left quadrant): These are the potential star products—projects with a high likelihood of success, and which are also expected to yield a very high reward. Most firms wished they had more of these. Company T has two such Pearl projects, and one of them has been allocated considerable resources (denoted by the size of the circles).

One attraction of this bubble diagram model is that it forces management to deal with the resource issue.

• *Oysters* (lower left): These are the *long-shot* projects—projects with a high expected payoff, but with low likelihood of technical success. They are the projects where technical breakthroughs will pave the way for solid payoffs. Company T has three of these; none receives many resources.

• *Bread and Butter* (upper right): These are small, "no-brainer" projects—high likelihood of success but low reward. They include the many fixes, extensions, modifications, and up-dating projects of which most companies have too many. Company T has a typical over-abundance of such projects (note that the large circle here is actually a cluster of related renewal projects). More than 50 percent of spending goes to these "bread and butter" projects in Company T's case.

• *White Elephants* (lower right): These are the low-probability and low-reward projects. Every business has a few white elephants—they are inevitably difficult to kill, but Company T has far too many. One-third of the projects and about 25 percent of Company T's spending falls in the lower right White Elephant quadrant.

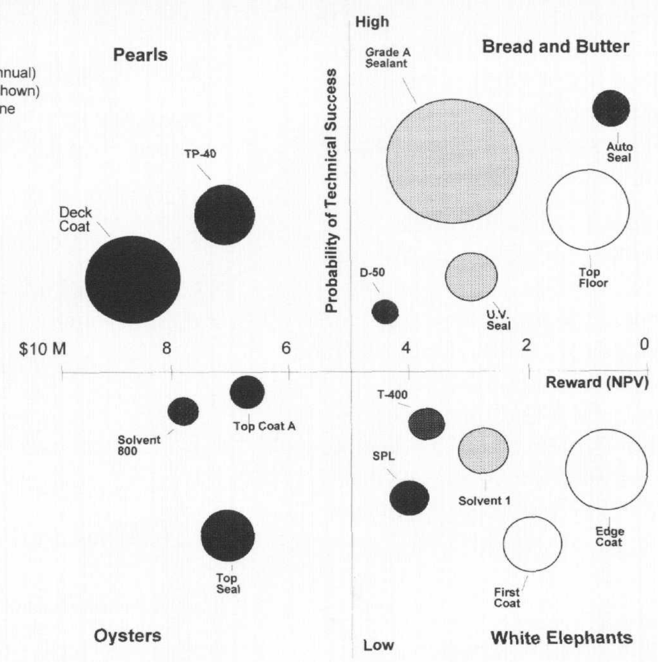


Figure 2.—Company T (a chemical company) uses this bubble diagram to represent its portfolio of new-product projects. Adapted from SDG model.

One attraction of this bubble diagram model is that it forces management to deal with the resource issue. Given finite resources (e.g., a limited number of people or money), *the sum of the areas of the circles must be a constant.* That is, if you add one project to the diagram, you must subtract another; alternatively, you can shrink the size of several circles. The elegance here is that the model forces management to consider the resource implications of adding one more project to the list—that some other projects must pay the price!

Also shown in this bubble diagram is the product line with which each project is associated (via the shading or cross-hatching). A final breakdown which Company T reveals via color is timing (not shown). Here, hot red means "imminent launch" while blue is cold and means "an early-stage project." Thus, this apparently simple risk/reward diagram shows a lot more than simply risk and profitability data; it also conveys resource allocation, timing, and spending breakdowns across product lines.

Dealing with Uncertainties

■ *3M's ellipses:* One problem with Company T's bubble diagram is that it requires a point estimate of both the reward, namely the likely or probable NPV, as well as the probability of success. Some 3M businesses use a variant of the bubble diagram to effectively portray uncertain estimates. In calculating the NPV, optimistic and pessimistic estimates are made for uncertain variables, leading to a range of NPV values for each project. Similarly low, high and likely estimates are made for the probability of technical success. The result is Figure 3, in which the size and shape of the bubbles reveal the uncertainty of projects; small bubbles mean highly certain estimates on each dimension, whereas large ellipses mean considerable uncertainty (a high spread between worst case and best case) for that project.

■ *Monte Carlo simulation:* Procter & Gamble and Company M (a U.S. medical products firm) use Monte Carlo simulation to handle probabilities. P&G's portfolio model is a three-dimensional portfolio model created by three-dimensional CAD software; the three axes are NPV, time to launch, and probability of commercial success (*15*). Similarly, Company M uses a portfolio model similar to Company T's in Figure 3. In both firms, in order to account for commercial uncertainty, every variable—revenue, cost, launch timing, and so on—requires three estimates: a high, low and likely estimate. From these three estimates, a *probability distribution curve* is calculated for each variable. Next, random scenarios are generated for the project using these probability curves as variable inputs. Thousands of scenarios are computer-generated (hence, the name Monte Carlo, for thousands of spins of the wheel), and the result is a distribution of financial outcomes. From this, the expected NPV and its range is determined—an NPV figure in which all commercial outcomes and their probabilities are figured. P&G shows this range of NPVs as simply an I-beam drawn through the spheres (in P&G's three-dimensional bubble diagram, the bubbles become spheres).

Portfolio Maps Derived From Scoring Models

Reckitt & Colman uses a simplier risk–reward diagram, one of the many visual charts that comprise R&C's portfolio method (*16*). The most useful portfolio map, in

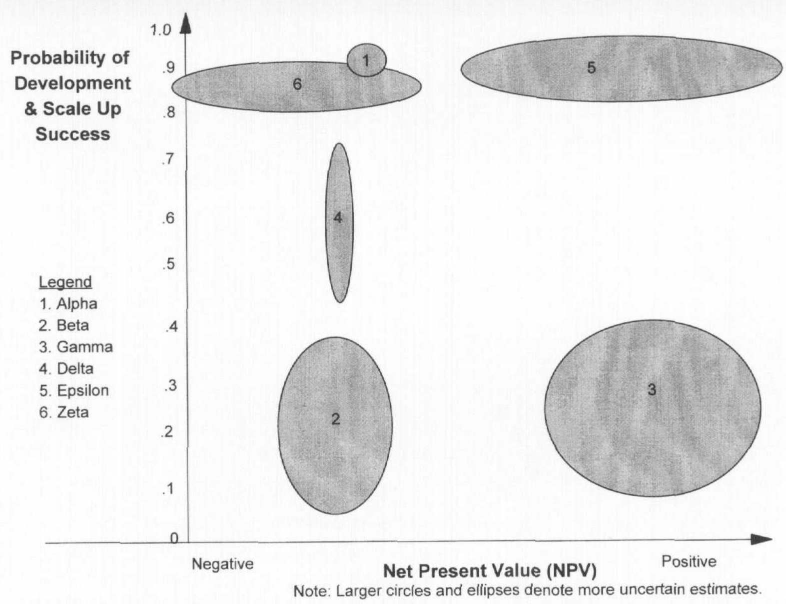


Figure 3.—3M Co. uses this bubble diagram to make uncertain estimates visible. Larger ellipses signify greater uncertainty.

management's view, is their "ease versus attractiveness" chart. Here, the axes are "concept attractiveness" and "ease of implementation" (Figure 4). Both axes are constructed from multi-item scored scales (scoring models).

Concept attractiveness is made up of scores on six items, including, for example, purchase intent, product advantage, sustainability of advantage, and international scope. Similarly, *ease of implementation,* the second axis, is composed of scored items, including the firms' technological strengths and the expected absence of problems in terms of development, registration, packaging, manufacturing, and distribution. Thus, R&C uses a scoring model, but in this case to construct the axes of the two-dimensional portfolio bubble diagram.

A variant on this scoring approach is employed by Speciality Minerals (*17*). A scoring model is used to make Go/Kill decisions at gates and also to rank-order projects on a prioritization list. Seven factors are considered in the firm's scoring model: business-unit interest, customer interest, sustainability of competitive advantage, technical feasibility, credibility of the business case, fit with technical/manufacturing capabilities, and financial attractiveness. These *same factors* then provide the input data to construct the bubble diagram (not shown). For example:

- The vertical axis, labelled "value to the corporation", is composed of the financial attractiveness and competitive advantage factors, added together in a weighted fashion.
- The horizontal axis is "probability of success" and is made up of three factors: customer interest, technical feasibility, and fit with technical/manufacturing capabilities (again, a weighted addition). The unique feature here is that this company's seven-factor scoring model does double duty: It is the basis for Go/Kill decisions at gate reviews, and it provides five factors (and data) to construct the two axes of the portfolio bubble diagram. The gate decisions are thus closely linked to portfolio reviews.

Traditional Charts

There are numerous parameters, dimensions or variables across which one might wish to seek a balance of projects. As a result, we witnessed an endless variety of histograms and pie charts which help to portray portfolio balance. Some examples:

Timing is a key issue in the quest for balance. One does not wish to invest strictly in short-term projects, nor totally in long-term ones. Another timing goal is for a steady stream of new-product launches spread out over the years—constant "new news", with no sudden log-jam of product launches in any one year. The histogram in Figure 5 captures the issue of timing and portrays the distribution of resources to specific projects according to year of launch. For example, Company T allocates 35 percent of monies to four projects, all due to be launched within year 1. Another 30 percent of resources is being spent on four projects whose projected launch date is year 2, and so on.

Another timing issue is *cash flow.* Here, the desire is to balance one's projects in such a way that cash inflows are reasonably balanced with cash outflows in the business. R&C thus produces a timing histogram that portrays the total cash flow per year from all projects in the portfolio over the next few years (not shown).

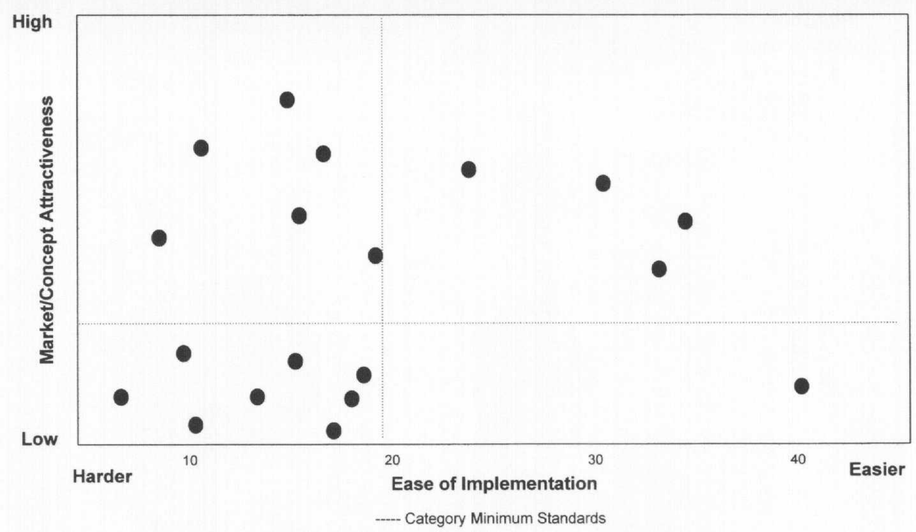


Figure 4.—Reckitt & Colman considers an "ease vs. attractiveness chart to be the most useful portfolio map. Both axes are based on a weighted addition of multiple items (much like a scoring model). Solid circles represent new-product projects.

Project types is yet another vital concern. What is your spending on genuine new products versus product renewals (improvements and replacements), product extensions product maintenance, cost reduction of process improvements? And what should it be? Pie charts that capture the spending split across project types are common and were found in just about every company we studied.

Market, products and technologies provide another set of dimensions across which managers sought balance. The question faced is: Do you have the appropriate split in R&D spending across your various product lines? Or across the markets or market segments in which you operate? Or across the techologies you possess? Pie charts are appropriate for capturing and displaying this type of data.

The Issue of Portfolio Balance

There is much to be said for achieving the right balance of projects in a portfolio; that is, there is more to life than simply achieving a high-value portfolio—balance is also an issue. The trouble is that achieving balance—or selecting an appropriate tool to help achieve balance—is easier conceptually than in practice.

What impressed us was how many intricate and ingenious methods and diagrams companies had invented to deal with balance. We could have filled an entire book with the maps, bubble diagrams and pie charts that we discovered. In spite of all this cleverness, however, there remain problems with the quest for balance:

1. Some of the more popular bubble diagrams suffered the same fate as the maximization models previously outlined; namely, they rely on substantial financial data when often these data are either unavailable or, at best, uncertain. Witness the popular risk–reward bubble

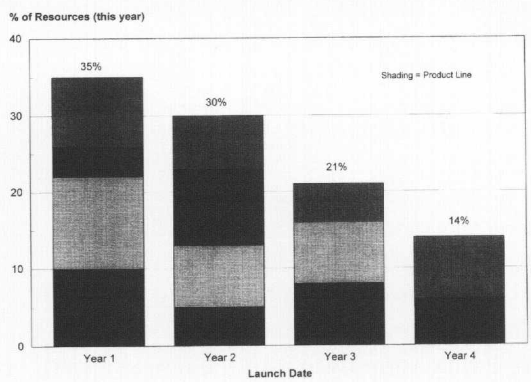


Figure 5.—Distribution of resources among individual projects over time is captured in this histogram.

There is more to life than simply achieving a high-value portfolio—balance is also an issue.

diagrams (Figures 2 and 3) in which NPV is one of the axes.

2. There is the problem of information overload. "Maps, endless maps!" was the complaint of one exasperated executive as he leafed through more than a dozen maps plotting everything versus everything in his firm's portfolio method. Very few companies had even attempted to use all the maps and charts recommended.

3. These methods are information display, not decision models *per se.* Unlike the value maximization methods, the result is not a convenient rank-ordered list of preferred projects. Rather, these charts and maps are only a starting point for discussion. Management still has to translate the data into prioritization decisions. Some failed; too many maps, or the wrong maps, may have contributed.

4. It was not clear what the "right balance" of projects was. Managers could stare all they wanted at various charts, but unless a portfolio was obviously and extremely out of balance (as in Company T's Figure 2), how does one know whether or not one has the right balance? If one lacks an idea of what the right balance is in the first place—the *what should be*—then all these balance maps and charts—the *what is*—are meaningless: What is one comparing the existing balance against? A portfolio manager at Hewlett-Packard mused about the possibility of "having rules of thumb for optimal portfolio balance," much like the stock market portfolio manager has.

5. Finally, it wasn't clear in every case what one did with the charts and maps. At R&C, the initial inclination was to make these maps part of the gate meeting. After a few attempts, this practice was halted, as it merely added to the confusion (the company has since worked out a better method of integrating portfolio and gate decisions). At R&C, electronic portfolio maps were also used at gate meetings, but only a few times before they, too, gave up. Company G uses the maps as an after-the-fact course correction—"to make sure we have the right balance." But it was never clear what would happen if the "wrong balance" ever occurred; would management immediately start canceling projects, and approving others in the queue?

The fact that portfolio balance methods are far from perfect does not mean they should be dismissed outright. Certainly not! But such approaches should be used with care; the choice of maps (which axes to use in the plots, for example) and charts (which parameters to show) must be well thought out. Avoid the temptation to portray too many maps and charts, and be sure to test their use in portfolio reviews or gate meetings before adopting them.

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To Be Continued

Goal 3, linking the portfolio to the business's strategy, is discussed in Part 2 of this report, forthcoming in the next issue of *Research • Technology Management.* We conclude with a critical look at the problems and issues identified in the study, offer insights into effective portfolio management, and then recommend our own approach and some solutions.

Acknowledgement

The research reported in this article was generously supported by grants from: Esso Chemical Canada (Exxon in Canada) and the Innovation Research Centre at the Michael G. DeGroote School of Business, McMaster University.

References and Notes

1. The entire study and full results are available in detail in the authors' report: *Portfolio Management for New Products,* McMaster University, Hamilton, Ontario, Canada, 1997. It may be ordered for $30.00 (Visa Card only) from Edgett at (905) 525-9140, ext. 27437.
2. Roussel, P., K. Saad and T. Erickson. *Third Generation R&D: Managing the Link to Corporate Strategy.* Boston, Massachusetts: Harvard Business School Press and Arthur D. Little Inc., 1991.
3. Griffin, A. and A. Page. "An Interim Report on Measuring Product Development Success and Failure." *Journal of Product Innovation Management 9,* 1 (1993): pp. 291–308.
4. Page, Albert L. "Assessing New Product Development Practices and Performance: Establishing Crucial Norms." *Journal of Product Innovation Management* 10, 4 (1993): pp. 273–290.
5. Archer, N. P. and F. Ghasemzadeh. "Project Portfolio Selection Techniques: A Review and a Suggested Integrated Approach." Innovation Research Centre Working Paper No. 46, McMaster University, 1996.
6. Baker, N. R. "R&D" Project Selection Models: An Assessment." *IEEE Transactions on Engineering Management.* EM-21, 4 (1974): pp. 165–170.
7. Baker, N. R. and W. H. Pound. "R&D" Project Selection: Where We Stand." *IEEE Transactions on Engineering Management.* EM-11, 4 (1964): pp. 124–134.
8. Danila, N. "Strategic Evaluation and Selection of R&D Projects." *R&D Management* 19, 1 (1989): pp. 47–62.
9. Liberatore, M. J. "A Decision Support System Linking Research and Development Project Selection with Business Strategy." *Project Management Journal* 19, 5 (1988): pp. 14–21.
10. Although we were principally interested in portfolio management for new products, to the extent that technology resources used in new products are also required for other types of projects, portfolio management must consider the fact that new-product projects compete against process developments, product maintenance projects and even fundamental research projects.
11. This decision rule of rank order according to the ratio of what one is trying to maximize divided by the constraining resource seems to be an effective one. We did simulations with a number of random sets of projects, and found that this decision rule worked very well—truly giving "maximum bang for buck"!
12. Taken from internal documents and discussions with Patricia Evans of Strategic Decisions Group.
13. Matheson, D., J. Matheson and M. Menke. "Making Excellent R&D Decisions." *Research • Technology Management* (November–December 1994): pp. 21–24.
14. P. Evans. "Streamlining Formal Portfolio Management." *Scrip Magazine* (February 1996).
15. This unique three-dimensional portfolio diagram is still experimental at P&G, and is being developed by Corporate New Ventures.
16. R&C is a major multinational consumer goods firm, headquartered in the United Kingdom. In North America, familiar brands sold by R&C include Easy-Off oven cleaner, Air Wick air freshener, Lysol disinfectant cleaners, and Woolite fabric wash.
17. Specialty Minerals, a spin-off company from Pfizer, produces specialized industrial mineral products.