Managing Technology Development Projects

Overview

Technology development projects are the foundation or platform for new products and new processes and thus are vital to the prosperity of the modern corporation. But these basic research or fundamental knowledge-build projects are often mismanaged because companies employ the wrong process to manage them or apply inappropriate financial criteria for project selection. The result is that technology developments have become increasingly rare in the typical company's development portfolio. To better manage such projects, leading companies have adopted a unique Stage-Gate® process specially tailored to the needs of technology development projects. This process consists of three stages and four gates, and feeds the front end of the typical new product process. Scorecards and the use of tailored success criteria are used to rate and rank these technology projects, while the "strategic buckets" approach to portfolio management ensures that dedicated resources are deployed for these higher-risk projects.

—ROBERT G. COOPER

Key Concepts: Technology development, Stage-Gate, scorecard, portfolio management.

THE term "technology development" refers to a special class of development projects where the deliverable is new knowledge, new technology, a technical capability, or a technological platform. These projects, which include fundamental research projects, science projects, basic research, and often technology platform projects, often lead to multiple commercial projects—new product or new process development.

Technology development projects are a special breed: although they represent a small proportion of effort in the typical company's development portfolio, they are vital to the company's long-term growth, prosperity and sometimes even survival. These projects also stand out because they are often mismanaged or mishandled, resulting in few benefits to the company. The chronicles of many, if not most, large corporations are replete with horrific stories about huge technology projects that led to nothing after spending millions of dollars, or worse yet, were cancelled prematurely, thus forgoing millions in potential profits.

This article outlines proven approaches to selecting and managing such venturesome projects—approaches that recognize that traditional management techniques, such as phase-review, Stage-Gate® or PACE® with their elaborate checklists, scorecards, deliverables lists, and financially-based Go/Kill criteria, are inappropriate for such projects *(1–3)*.

WHAT'S SO SPECIAL?

Technology development (TD) projects are indeed a very different type of development project. First, they are increasingly *rare*—the average business's R&D portfolio has shifted dramatically to smaller, shorter-term projects such as product updates, modifications and fixes over the last 15 years (4). With the exception of a handful of best-practice companies, gone are the days when portfolios were replete with advanced technology, technology breakthrough and true innovation development projects *(5)*.

Because these growth engines provide the platforms for the next generation of products and processes, companies have to manage them better!

This dearth of innovative projects is in part due to management's preoccupation with the *short term and immediate financial results*, which usually precludes undertaking venturesome development projects *(6)*. When resources are tight, managers take few chances—they elect the "sure bets," which are typically the smaller, closer-to-home projects. Here's a typical comment *(7)*:

> *My business has a limited R&D budget. I can't afford to risk a major percentage of that budget on a handful of big projects. I've got to hedge my bets here, and pick the smaller and lower risk ones. If I had a larger R&D budget, then I might tackle some more venturesome projects.* . . . Senior R&D executive in a $300 million business unit of a major manufacturing conglomerate.

Additionally, the business's inability to handle these projects effectively also contributes to a reluctance to undertake more of them. In short, because these projects are mismanaged, the results are often negative, which creates a real fear of ever undertaking such a project again! Management becomes risk averse.

A second factor that makes these TD projects so special is that they are often the foundation or platform for a new product line or an entirely new business. In short, TD projects are important to profitability in that they help to de-commoditize the business's product offerings. They are the breakthroughs, disruptive technologies and radical innovations that create the huge growth opportunities and superlative profits *(8)*.

Exxon Chemical's Metallocene project is a classic example. Here, a fundamental research study into a new polymerization catalyst yielded some early "interesting research results," namely polyolefin materials with unusual technical properties. What started out as a early-stage research project in the 1980s ultimately resulted in an entirely new class of polymers with engineering properties and a billion-dollar business for Exxon Chemical.

Don't Use Traditional Methods for Non-Traditional Projects

A final reason that TD projects are so special is that they are *fragile*. If one applies traditional management techniques to non-traditional projects, much damage is done. For example, force-fitting a TD project through your normal new-product system will create considerable frustration on the part of the project team, will result in unnecessary or irrelevant work, and could even kill an otherwise high-profit-potential initiative.

Exxon Chemical was one of the first companies in the United States to recognize that such research or technology development projects required special treatment, and that ramming them through their traditional management processes would do much harm. Thus, by the 1990s, Exxon Chemical had designed and implemented a special methodology based on stage-and-gate techniques to handle such high-risk technology projects (9).

Much damage is done by applying traditional management techniques to non-traditional projects.

The fact is that traditional systems simply do not work for these special TD projects. Why? Traditional new-product processes are designed for fairly well-defined and predictable projects; technology developments, however, are by their nature high-risk projects with many unknowns and great technical uncertainties. For example, early in the life of such projects, the likelihood of technical success may be quite low, and a probable technical solution often cannot be envisioned. It may take months or years of lab work to see a technical solution and to gain confidence in a positive technical outcome.

Similarly, the traditional new-product process requires a full business case and financial analysis before heavy commitments are made. But in a TD project, the commercial prospects for the new technology are often unclear, especially near the beginning of the project when these commitment decisions are required.

In the Exxon Chemical Metallocene project, for example, when experimental work first began, it wasn't clear whether this would lead to a new plastic, or perhaps a new fuel additive—all the researchers had in the early days was "some gummy stuff with interesting properties": the precise direction of the project would not become clear until the researchers had done more work at considerable expense. This is not exactly the reassurance that a short-term, financially-driven executive wants to hear!

Many of the activities required of most companies' new-product processes simply don't fit the TD project. Review any company's new-product process and invariably there is a list of required tasks such as "undertake a competitive analysis," "do voice of customer work" and "define the product benefits to the user." That's fine when one knows what the market and product are. But how does one undertake such mandatory activities when the market is unknown and the product not even defined? Moreover, most companies new product processes require a list of deliverables at the completion of each stage, deliverables such as "a business case" or a "commercialization plan." Again, these are relatively meaningless concepts when the product and market have not yet been defined. As one frustrated project leader put it:

> *How can I be expected to do a market analysis when I haven't even defined the product, let alone the market yet. I'm not even sure what this technology is capable of in terms of delivering improved technical performance.*

Finally, the Go/Kill criteria used to rate and prioritize development projects as found in most company's stage-and-gate development processes again assume projects that are fairly well-defined. For example, an Industrial Research Institute study revealed that 78 percent of businesses rely heavily on financial criteria to select projects: criteria such as projected annual profits, NPV (net present value) and expected sales (10). When qualitative criteria are employed, according to the same study, the most popular are leveraging core competencies (for example, the project's fit with the plant, and fit with the firm's base technology), the expected payoff, and the perceived risk level. These quantitative and qualitative criteria are fine for the majority of development projects, but not so good for technology developments. A seasoned R&D executive in a major corporation summarized the situation this way:

> *Using traditional Go/Kill criteria—NPV. KOI (return on investment) and the like—will almost guarantee that new technology projects are killed in our company simply because of the unknowns, uncertainties, risks and the step-out nature of such projects. Our selection rules are very risk averse and geared towards short-term projects.*

USE A PROCESS DESIGNED FOR TD PROJECTS

For some years, leading product developers have relied on idea-to-launch processes, such as Stage-Gate®, to drive new-product projects to market *(11)*. The conclusion at a conference of the Product Development Management Association (PDMA) that focused on technology developments and fuzzy front-end projects was that "many companies have dramatically improved development cycle time and efficiency by implementing formal Stage-Gate™ "systems" but that the front end remained a mystery *(12)*. The consensus is that some type of rigorous stage-and-gate process is desirable for TD projects, but the process must be custom designed for these types of projects *(13)*.

Some type of rigorous stage-and-gate process is desirable but it must be custom-designed.

Figure 1 illustrates a typical TD process, which has been adopted in leading companies that undertake fundamental research projects; it consists of three stages and four gates *(14)*.

- The stages are shown as boxes in Figure 1. Each stage consists of a set of best-practice activities to be undertaken by the project team. These activities are designed to acquire vital information and thereby reduce the unknowns and hence the risk of the project from stage to stage. The outcome of each stage is a specified set of deliverables.

- The gates, designated by diamonds, are the Go/Kill decision points. Here, management meets with the project team to decide whether the project merits additional funding and resources to move to the next stage. If Go, resources are committed at the gate and the project and team move forward.

Here is a quick walk through the typical TD process (see Figures 1 and 2):

Discovery.—The trigger for the process is the first stage, involving discovery or idea generation. Quality ideas are essential to a successful technology program and thus technology ideas from multiple sources must be sought for consideration at Gate 1. While idea generation is often done by scientists or technical people, it can also be the result of other activities, such as:

- A strategic planning exercise, where strategic arenas are identified, and possible TD research directions are mapped.
- Technology forecasting and technology roadmapping.
- Brainstorming or group creativity sessions focusing on what might be.
- Scenario generation about future market and technological possibilities.
- Customer visitation programs and voice-of-customer initiatives.
- Active idea solicitation campaigns within the organization.

Gate 1 *Idea Screen*—This first gate is the idea screen, the initial decision to commit a limited amount of time and money to the research project. This gate should be a *gentle screen*, which poses the question: Does the idea merit expending any effort at all? Criteria for Go are largely qualitative, are scored at the gate review by the gatekeepers, and should include such items as:

- Strategic fit and impact.
- Strategic leverage.
- Likelihood of technical success.
- Likelihood of commercial success.
- Reward or the "size of the prize" if successful.

The Gate 1 gatekeeper or decision-making group is typically composed of senior R&D

Figure 1. The technology development Stage-Gate® process is specially designed for TD projects—three stages and four gates up to an Applications Path Gate.

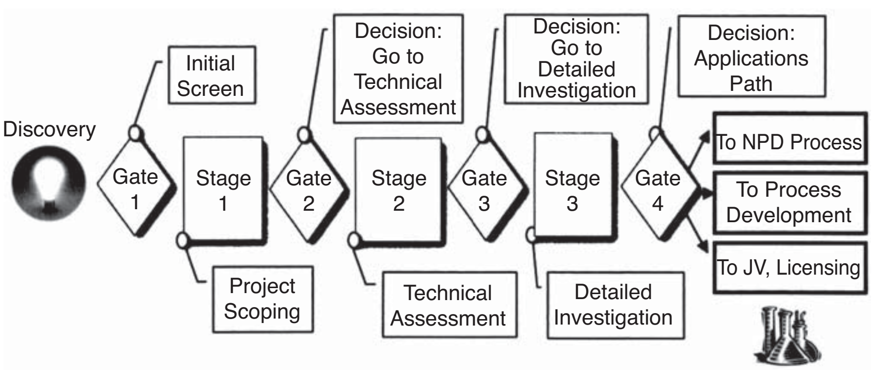
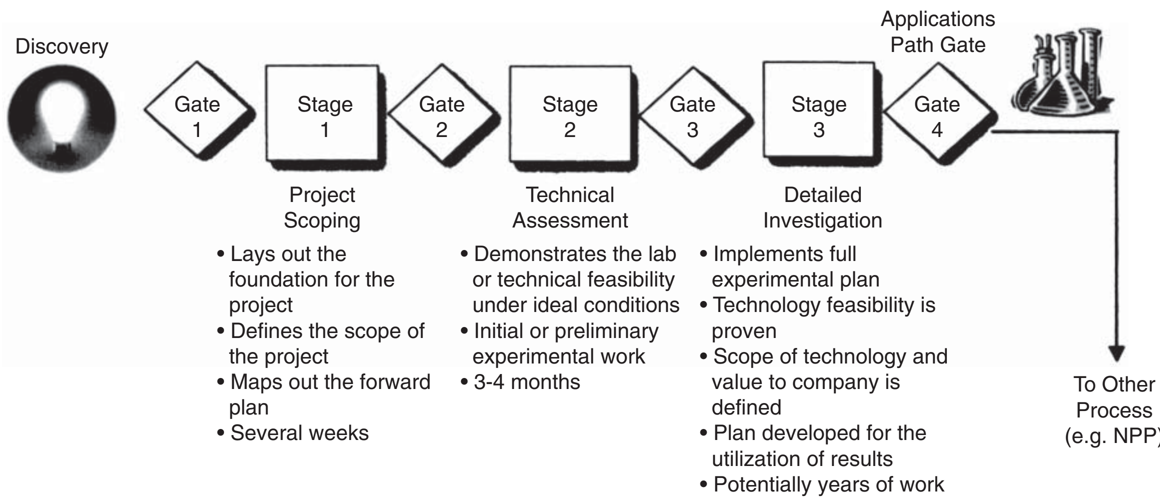


Figure 2. The TD project moves from the Scoping Stage—a relatively simple stage—through to the Detailed Investigation Stage, which can entail person-years of experimental work.



people, such as the corporate head of technology (VP R&D or CTO), other senior R&D people, along with representatives from corporate marketing and business development to ensure commercial input.

Stage 1 *Project Scoping*—The purpose of this Scoping stage is to build the foundation for the research project, define the scope of the project, and map the forward plan. The effort is limited, typically to not much more than two weeks. Stage 1 activities are conceptual and preparation work (see Figure 2), and include a technical literature search, patent and IP search, competitive alternatives assessment, resource gaps identification, and a preliminary technical assessment.

Gate 2 *Go To Technical Assessment*—This second screen is the decision to begin limited experimental or technical work in Stage 2. Like Gate 1, this gate is also a relatively gentle screen, and poses the question: Does the idea merit undertaking limited experimental work? Gate 2 is again largely qualitative, and does not require financial analysis (because the resulting product, process or impact of TD are still largely unknown). The gatekeepers are the same as at Gate 1.

Stage 2 *Technical Assessment*.—The purpose of Stage 2 is to demonstrate the technical or laboratory feasibility of the idea under ideal conditions. This stage entails initial or preliminary experimental work, but should not take more than 1–2 person-months, and last no longer than 3–4 months. Activities here typically include undertaking a thorough conceptual technological analysis, executing feasibility experiments, developing a partnership network, identifying resource needs and solutions to resource gaps, and assessing the potential impact of the technology on the company.

Gate 3 *Go to Detailed Technical Investigation*.—Gate 3 is the decision to deploy resources beyond 1–2 person-months, and opens the door to a more extensive and expensive investigation, Stage 3. This gate decision is thus a more rigorous evaluation than at Gate 2, and is based on new information from Stage 2. Gate criteria resemble those listed for Gate 1 previously, but with more and tougher sub-questions, and answered with benefit of better data.

The Gate 3 gatekeepers usually include the corporate head of technology (VP R&D or CTO), other senior technology or R&D people, corporate marketing or business development, and the heads of the involved businesses (e.g., general managers). Because Gate 3 is a heavy commitment gate, senior managers of the business units that will take ownership of the resulting technology should be the Gate 3 gatekeepers. Their insights into the commercial viability of the project are essential at Gate 3; further, more early engagement ensures a smoother transition to the business unit once the commercial phase of the project gets underway.

Stage 3 *Detailed Investigation*.—The purpose of Stage 3 is to implement the full experimental plan, to prove technological feasibility, and to define the scope of the technology and its value to the company. This stage could entail significant expenditures, potentially person-years of work. Besides the extensive technical work, other activities focus on defining commercial product or process possibilities, undertaking market, manufacturing and impact assessments on these possibilities, and preparing an implementation business case. Sound project management methods are employed during this lengthy stage, including periodic milestone checks and project reviews. If the TD project veers significantly off course, or encounters serious barriers to completion during Stage 3, the project is red-flagged and cycled back to Gate 3 for another Go/Kill decision.

Gate 4 *The Applications Path Gate*.—This is the final gate in the TD process and is the "door opener" to one or more new-product or process development projects (see Figure 3). Here the results of technical work are reviewed to determine the applicability, scope and value of the technology to the company, and the next steps are decided. Note that this Gate 4 is often combined with an early gate in the usual product development process (for example, with Gate 1, 2 or 3 as shown in Figure 3). Gate-keepers are typically the senior corporate R&D people, corporate marketing or business development, plus the leadership team from the relevant business that will assume ownership of the resulting commercial development projects.

How TD Process Feeds the Traditional Process

The final gate of the TD process is the Applications Path Gate, which marks the end of the TD project but potentially the beginning of multiple commercial projects. It is here that the project team presents their conclusions about the commercial prospects for the technology, based on technical work to date and several quick commercial scoping exercises. At this point, multiple new-product projects could be initiated and feed the typical new-product process, as shown in Figure 3. The start points are usually Gates 1, 2 or 3 of the new-product process, depending on how well defined the proposed new projects are. Alternatively, if the commercial result is a new or improved production process, then the appropriate process-development projects are defined here and routed accordingly.

The TD project may also result in a licensing opportunity or perhaps even a joint venture with another corporation. The point is that the Applications Path Gate determines the direction for the commercialization of the technology from this point onward.

PICKING THE RIGHT PROJECTS

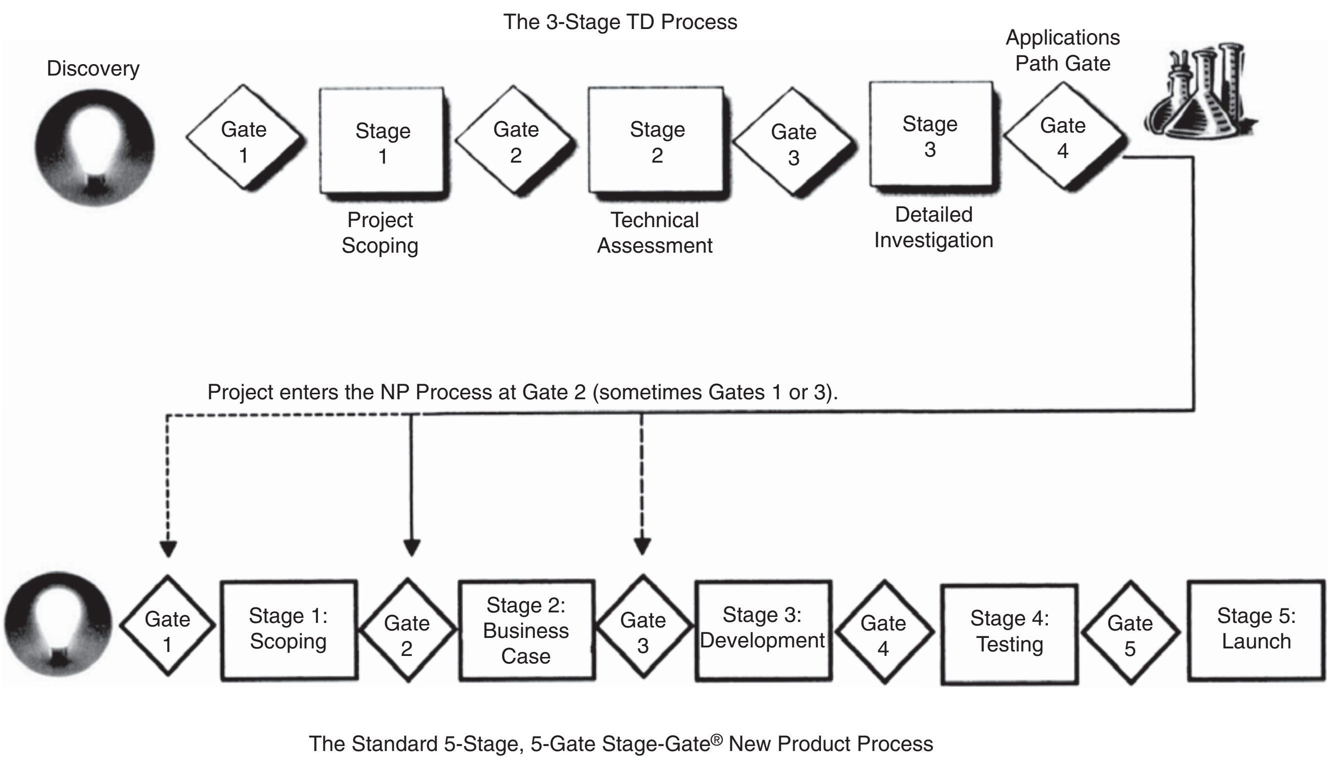
Making the resource commitment decisions for TD projects, especially in the early stages, is problematic for many companies. Clearly, traditional tools, such as financial analysis and profit criteria, are not too useful. In TD projects with much undefined, the level of uncertainty is so great that numerical estimates of expected sales, costs, investment, and profits are likely to be grossly in error. There exist many uncertainties in the typical TD project, but the one thing you can be certain about is that *your numbers are always wrong*. Indeed there is considerable evidence that businesses that rely strictly on financial tools and criteria to select projects end up with the lowest-value development portfolios *(15)*. As one executive declared, in noting the deficiencies of his company's sophisticated financial-analysis methods for project selection:

It's like trying to measure a soft banana with a micrometer! Our evaluation tools assume a level of precision far beyond the quality of the data available!

Not surprisingly, this executive's financial evaluation tool tended to favor predictable and close-to-home projects at the expense of technology development projects.

Best performers adopt a combination of evaluation techniques and criteria for making Go/Kill decisions on TD projects *(16)*. The research suggests that no one method works best across the board and can do it all! First consider using a *scorecard approach*, which looks at multiple facets of TD projects, from strategic to technical issues. Note that this TD scorecard is different than the one that should be used for new product projects; a best-practice model for Gate

Figure 3. The typical technology development (TD) process spawns multiple "commercial projects" that can feed the new-product process at Gates 1, 2, or 3.



3 for TD projects is shown in Figure 4 *(17)*. Scorecards are highly rated by users as a solid decision-making method, and tend to yield more efficient and more effective Go/Kill choices, higher-value projects and a portfolio of strategically aligned projects *(18)*.

In the scorecard approach, the project in question is presented by the project team at each gate meeting in Figure 1, and a thorough and facilitated gate discussion ensues. Next, the gatekeepers score the project on zero-to-ten scales, as in Figure 4. The resulting scores are then combined to yield an overall *project attractiveness score*. This scoring exercise and final score become key inputs to the Go/Kill decision (although many users of this approach claim that it is the process—a senior decision-making group going through a set of key questions, debating their scores, and reaching closure on each—that provides the real value, and not so much the final score itself). Although the sample scorecard in Figure 4 is for Gate 3, note that most businesses use the same high-level criteria from gate to gate for consistency, with the detailed or sub-questions

Figure 4. Use a scorecard (0–10 scale) to rate and prioritize TD projects.

	Score = Zero	*Score = Ten Out of Ten*
1. Business Strategy Fit		
Congruence	Only peripheral fit with our businesss' strategy.	Strong fit with several key elements of strategy.
Impact	Minimal impact; no noticable harm if project is dropped.	The business's future depends on this project. project.
2. Strategic Leverage		
Proprietay position	Easily copied; no protection.	Position protected through patents, trade secrets, raw material access, etc.
Platform for growth	Dead end; one-of-a-kind; one-off.	Opens up many new product possibilities.
Durability (technical and marketing)	No distinctive advantage; quickly leapfrogged by others.	Long life cycle with opportunity for incremental spin-offs.
Synergy with corporate units	Limited to a single business unit.	Could be applied widely across the corporation.
3. Probability of Technical Success		
Technical gap	Large gap between solution and current practice; must invent new science.	Incremental improvement; easy to do; existing science.
Project Complexity	Difficult to envision the solution; many hurdles along the way.	Can already see a solution; straightforward to do.
Technology skill base	Technology new to company; almost no skill internally.	Technology widely practiced withing the company.
Availability of people and facilities	Must hire and build.	people and facilities immediately available.
4. Probablility of Commercial Success (in the case of a TD project with potential for new products)		
Market need	Extensive market development required; no apparent market exists at present.	Product immediately responsive to a customer need; a large market exists.
Market maturity	Declining markets.	Rapid-growth markets.
Competitive intensity	High; many tough competitors in this field.	Low; few competitors; week competition.
Commercial applications development skills	New to company; we have no/few commercial applications skills here; must develop.	Commercial applications skills and people already in place in the company.
Commercial assumptions	Low probablility of occuring; very speculative assumptions.	Highly predictable assumptions; high probablility of occuring.
Regulatory and political impact	Negative.	Positive imoact on a high-profile issue.
5. Reward		
Contribution to profitability	Rough estimate: less than $10M cumulative over 5 years.	Rough estimate: more than $250M.
Payback period	Rough estimate: greater than 10 years.	Rough estimate: less than 3 years.
Time to commerical start-up	Greater than 7 years.	Less than 1 year.

becoming progressively tougher at successive gates.

Businesses that rely strictly on financial tools end up with the lowest-value development portfolios.

In addition to a gate scorecard, consider the use of *success criteria* as employed at Proctor & Gamble (19). Here the project team declares what they hope to achieve in order for the project to be considered "a success." Success criteria for TD projects include the achievement of certain technical results (e.g., positive lab test results) by a given date, attaining a certain technical performance improvement (e.g., a certain level of absorption in a new fiber technology), or the expected sales potential to be generated by the new technology (e.g., the size of the market that this technology might see potential in, if successful).

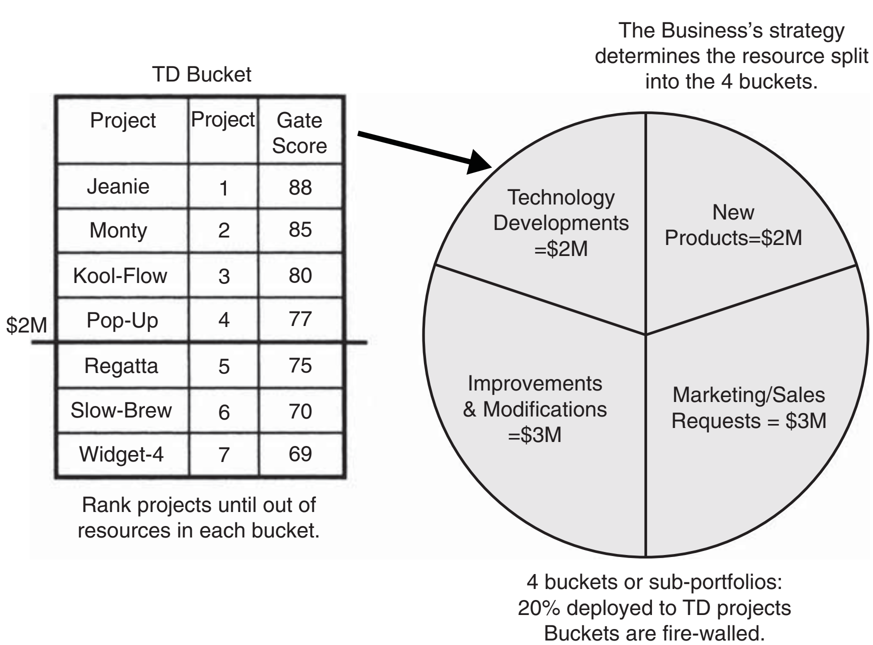
Success criteria are declared relatively early in the project, and on this basis, gatekeepers approve the project at the early gates. These criteria are reviewed and updated at each successive gate; if the project falls short of these success criteria at the next gate, it may be killed—for example, if certain technical results were not achieved by a given date or gate. The use of success criteria allows the project team to develop customized criteria to suit their project; it forces the team to submit realistic rather than grandiose expectations, and it creates accountability for the project team—something to measure the team against.

Ensuring Resources Are in Place

How does one ensure that resources will be available to undertake TD projects, especially with today's emphasis on short-term projects? Managements in a number of companies have recognized that significant resources have shifted from venturesome projects to small, lower-impact efforts. In order to correct this imbalance, they employ strategic buckets as a tool to ensure the right mix of projects—short-term versus longer-term or TD projects—in their portfolios *(10)*.

Strategic buckets is a portfolio management method that defines where management desires the development dollars to go, broken down by project type, market, geography, or product area *(20)*. Strategic buckets is based on the notion that *strategy becomes real when you start spending money*; thus, translating strategy from theory to reality is about making decisions on where the resources should be spent—strategic buckets. In the example in Figure 5, management begins with the business's strategy and then makes strategic choices about resource allocation: how many resources go to new products or to improvements or to technology developments'? With resource allocation now

Figure 5. Resources are strategically allocated by project type into strategic buckets by senior management.



firmly established and driven by strategy, projects within each bucket are then ranked against one another to establish priorities.

Note that projects in one bucket—such as technology developments—do not compete against those in another bucket, such as sales and marketing requests. If they did, in the short term, simple and inexpensive projects would always win out, as they do in many businesses. Instead, strategic buckets build firewalls between buckets. Thus, by earmarking specific amounts for technology developments, the portfolio becomes much more balanced. Note also that different criteria should be used to rate and select projects in each bucket. For example the relatively qualitative criteria in Fig. 4 work well in order to rank projects in the TD bucket, but for modifications and improvements or sales requests, clearly financial criteria—profits, savings or expected sales increase—are the best way to rank these projects.

Make Your TD Projects Pay Off

Technology developments are the engines of growth for many corporations and industries, providing the platforms for the next generation of new products and new processes. With most companies facing constrained resources and having a short-term focus, it is imperative that such projects be managed more effectively than in the past so that they truly do achieve their promised results. Adopting a TD Stage-Gate process, using custom-tailored Go/Kill scorecards and success criteria, and employing strategic buckets to ensure resource availability, are but some of the approaches that leading companies are adopting to handle these vital TD projects.

References and Notes

1. Stage-Gate® is a registered trademark of Product Development Institute Inc.; PACE® is a registered trademark ot’PRTM.
2. The argument that technology projects require a special version of Stage-Gate® has been voiced previously; see Koen, P. 2003. Tools and Techniques for Managing the Front End of Innovation: Highlights from the May 2003 Cambridge Conference. *Visions* XXVII, 4 (October).
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6. The reasons for the shift in portfolios are explored in (*4*).
7. Quotations are from over 100 problem-detection sessions held in companies, and from several studies by the author and co-workers; see for example the three-part *RTM* series beginning with: Cooper, R. G., Edgett, S. J. and Kleinschmidt, E. J. 2004. Benchmarking Best NPD Practices—I: Culture, Climate, Teams and Senior Management Roles. *Research-Technology Management* 47, 1 (Jan–Feb), pp. 31–43; also (*5*) and (*11*).
8. See for example: Christensen, C. M. 1997. *The Innovator’s Dilemma*. Harper Business, Harper Collins Publishers; and Foster, R. N. and Waterman, R. H. 1998. *Innovation: The Attacker’s Advantage*, Summit Books.

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11. See: PDMA studies: Adams, M. and Boike, D. 2004. PDMA Foundation CPAS Study Reveals New Trends. *Visions* XXVIII, 3 (July), pp. 26–29; and 2004. Cooper, R. G., Edgett, S. J. and Kleinschmidt, E. J. Benchmarking Best NPD practices—III: Driving New-Product Projects To Market Success. *Research-Technology Management* 47, 6 (Nov–Dec): pp. 43–55.
12. Source: Koen, P. in (*2*).
13. An early version of a technology model is described in: Eldred, E. W. and McGrath, M. E. 1997. Commercializing New Technology—I. *Research-Technology Management* 40, 1 (Jan–Feb) pp. 41–47; see also the model outlined in (*2*) and (*3*).
14. An earlier version of this model is outlined in Cooper, R. G. 2005. *Product Leadership: Pathways to Profitable Innovation* 2nd edition. New York, NY: Perseus Books, Chapter 7.
15. See (*10*) and Cooper, R. G., Edgett, S. J. and Kleinschmidt, E. J. 1999. New Product Portfolio Management: Practices and Performance. *Journal of Product Innovation Management* 16, 4 (July), pp. 333–351.
16. See (*10*) and Cooper, R. G., Edgett, S. J. and Kleinschmidt, E. J. 2002. Portfolio Management: Fundamental to New Product Success. In The *PDMA Toolbox for New Product Development*, edited by P. Beliveau, A. Griffin and Somermeyer, S. New York: John Wiley & Sons, pp. 331–364.
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20. This section is based on (*4*)', strategic buckets are explained in Portfolio Management for New Products (*10*).

Robert G. Cooper is professor of marketing at McMaster University's M.G. DeGroote School of Business, Hamilton, Ontario, Canada; ISBM Distinguished Research Fellow at Penn State University's Smeal College of Business Administration; and president of the Product Development Institute. He is the developer of the Stage-Gate® idea-to-launch process, and author of six books on product innovation management. He has won two Maurice Holland awards for the best paper published in Research-Technology Management in 1990 ("New Products: What Distinguishes the Winners?") and 1994 ("Debunking the Myths of New Product Development"). www.stage-gate.com

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