Strategic Management of Technical Functions

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PREVIOUSLY, MANAGERS WHO WANTED TO ASSESS THE TECHNICAL FUNCTION'S OVERALL STRATEGY HAVE HAD TO CONTENT THEMSELVES with fragmented, piecemeal approaches. This article provides general managers and technical function managers with a powerful, comprehensive framework encompassing the technical function's mission, objectives, strategic plan, and key policies. The article also discusses the process of adjusting these to changing conditions. The extensive set of indicators and the detailed bibliography will help managers benchmark their technical function's strategic management process.

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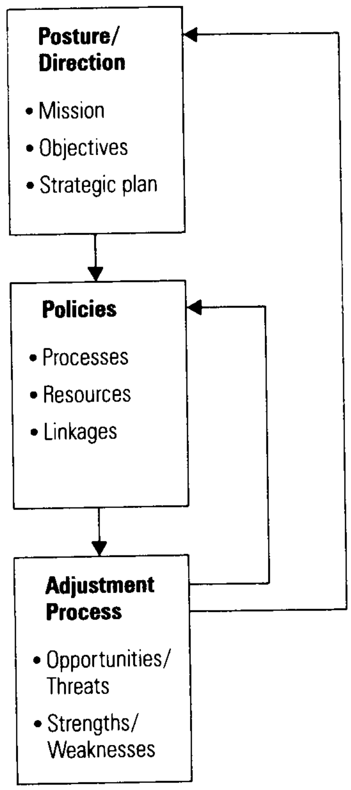
Too many businesses leave the technical functions — research and development (R&D), management information systems (MIS), manufacturing engineering, and so on — out of the business strategy process and exempt them from senior management's expectation that all the functions manage their internal operations strategically. Consider Xerox, whose 1970s decline and 1980s renaissance have been chronicled in numerous articles and two recent books.[1] While many factors contributed to these changes, Xerox's management of its technical organizations, in particular those involved in product development, appears to have been key. As Jacobson and Hillkirk describe it: "At one point during the 1970s, there was almost a complete breakdown in the company's product delivery system. Hundreds of millions of dollars were going into product development and very little was coming out."[2] But in the mid-1980s the 10 series won the Japanese Grand Prize for Good Design, and in 1989 Xerox won the first Baldrige Award.

While the Xerox story has a happy ending, managers need an alternative to crisis to alert them to the need for more effective strategic management of technical resources. Xerox managers credit competitive benchmarking with focusing their business turnaround in the 1980s. Xerox realized that, "compared with its competitors, its design cycles were long, its technologies old, and its product line limited."[3]

Technical functions need a way to benchmark not only their products but also their strategic management process. In the last decade, it has become increasingly evident that an effective overall business strategy must be buttressed by explicit and complementary strategies in each of the business's functions. Management experts have developed powerful conceptual frameworks for analyzing functional strategies in manufacturing, product planning, finance, and marketing. So far, however, technical function managers have not received comparable guidance. Despite the considerable literature on various specific management issues in R&D, MIS, and manufacturing engineering, there is no broadly accepted framework for assessing these units' overall functional strategies.

This article proposes such a framework. Borrowing liberally from established frameworks in the relevant literatures, we identify key elements of the technical function's strategy (TFS) and characterize four development stages for each of these elements. At the end of the article, we outline how managers can use the assessment to prioritize their improvement efforts. While we focus on product development functions, our experience suggests that

Figure 1 The Elements of Strategic Management



the same general framework, with appropriate modifications, is applicable to other technical functions.

Our framework will help managers evaluate both the decision-making process they use to set goals and how they achieve those goals. Our study of numerous technology-intensive companies reveals significant differences in the TFS approaches of successful and unsuccessful organizations — defining success by technical strength as well as sales growth rate and profitability.

Three TFS characteristics show up repeatedly as indicators of sustained technical accomplishment and business success:

• The technical function's overall posture and direction are clearly stated in successively more detailed versions — mission, objectives, strategic plans — and they are broadly accepted within the function and throughout the business.

• The technical function manages technology as a "business," with due attention to its key processes, resources, and internal and external linkages. Clearly articulated policies guide day-to-day decision making, policies that are comprehensive, compatible with strategic priorities, compatible with each other, and useful as decision guides, not just bureaucratic hurdles.

• The TFS can adapt as managers assess the strengths and weaknesses of their function's capabilities base and the opportunities and threats presented by the evolving market.

While the strategy problem is intrinsically complex, and there is no one right way to decompose it into constituent elements, we submit that three elements — posture/direction, policies, and adjustment processes — need to be addressed for the technical function to realize its potential contribution. We therefore use the model summarized in Figure 1 as a heuristic device, but not as a rigid template.

Previous discussions of technical function management have focused on specific subsets of these elements. Much has been written, for example, about how to define a technology posture — as first-to-market, fast follower, low-cost producer, and so on — but these discussions typically ignore the other facets of strategy. Other treatments have focused on policies without integrating them with direction and adjustment.

While organizations must craft the elements' content to their own circumstances, our research suggests that effective approaches have certain common features. In developing guidelines for evaluating TFS elements, we identified four levels of performance or development, which we characterize as follows:

1. **Isolated** — the technical function has few links to the rest of the business and makes a minimal contribution.

2. **Reactive** — the classic "firefighting" function responds to problems encountered by the rest of the business but never identifies its own long-term strategy.

3. **Proactive** — the technical function generates lots of new ideas and has a long-term strategy, but it is not well tuned to the other functions' needs or expectations.

4. **Integrated** — the function's activities both support the current business priorities and create new opportunities.

Our framework allows technical functions to rate themselves according to these stages on each element. Any given organization will rate itself differently on the different elements, but after conducting the analysis, most organizations can characterize their overall development stage and thus better define their improvement priorities.

We must emphasize that every organization needs to tailor the framework to its own situation using the characteristics most appropriate to its industry and strategic priorities. The framework is a prompt rather than a definitive standard, and the overriding consideration should be using it to discover strengths and weaknesses. Even so, we have been surprised by how little substantive adaptation is required in most cases.

Below, we review each element of the TFS and describe each stage's typical characteristics. For more information on the literature that has guided our thinking, please consult the bibliography following the article.

Identifying Posture and Setting Direction

While the specific posture and direction of a given technical function obviously need to be tailored to its particular context, we have found some common features in the way that more effective organizations characterize these key parameters. Effective organizations specify posture and direction at three successive levels of detail. At the most general level, the function has a clear sense of its purpose and values, in a word, its *mission.* We are accustomed to thinking of organizationwide missions, but the technical function needs its own, localized version. This mission is translated into measurable *objectives* that allow the function to continually assess its performance. A *strategic plan* identifies the path along which the function intends to meet its objectives and satisfy its mission.

Table 1 summarizes some common characteristics of these three elements at the four stages. We discuss them in detail below.

A Clear Mission

A Stage 1 technical function has no formal mission statement, and its driving force could be characterized as "stay within budget." Some Stage 2 functions have a mission statement, but it has not been effectively communicated to, nor is it fully accepted by, all levels within the function. Other Stage 2 functions define a posture, but do not articulate the posture's implications. Stage 2 functions often have a mission statement that is not accepted by the rest of the business. The function may believe its mission is to develop innovative products and processes, when in reality it helps the other functions solve short-term problems; it fights fires. When such technical functions try to innovate, their work is often rejected as academic or "blue sky."

Stage 3 missions, by contrast, are understood by all technical staff and recognize the business's technological needs. Typically, such missions are quite concrete. They distinguish different postures toward different subsets of products and processes. They might define their scope by specifying domains of use and domains of technology, which can be characterized as product targeted (one use-one technology), application targeted (one use-many technologies), technically targeted (many uses-one technology), or exploratory (many uses-many technologies).[4]

A Stage 4 technical function has a mission that is accepted and understood throughout the business and that reflects the function's potential contribution to the different segments of the value chain.[5] Staff clearly understand not only how the technical function supports the business strategy but also how technology can help shape the business strategy. The mission provides them with a unifying ethos.

Monsanto's R&D function has articulated a compelling mission.[6] The company challenges its scientists and engineers to follow three principles: (1) to pursue "a productive mix of short-, medium-, and long-term projects that match each operating company's objectives," with time frames ranging from less than five years to more than ten years; (2) to commit "to fundamental research that can lead to wholly new product opportunities"; and (3) to be "a leader in effective collaboration with great research universities."

Measurable and Compelling Objectives

The technical function must set objectives that can guide resource allocation decisions, help ascertain how well it is fulfilling its mission, and align it with other functions' objectives and strategies. Objectives are broader and more stable than goals tied to specific action plans.

A Stage 1 technical function has general objectives that either are not related to its mission (if it has one) or are not measurable. Stage 2 functions have objectives based on internal interests rather than external points of comparison. The danger of such an approach should be obvious. Ampex, for example, lost its dominant market share in video recording equipment in part because it persisted in defining performance characteristics in terms of broadcasting equipment rather than the emerging and much larger mass market.[7]

Stage 3 technical organizations usually have a balance of short- and long-term, low- and high-risk objectives. However, these objectives are often defined in terms of functional outputs, not how these outputs support key business objectives.

In contrast, Stage 4 objectives relate to business objectives. They are performance criteria that are meaningful both internally and to other functions. For example, 3M evaluates technical-function performance both by the percent of sales from products introduced in the last five years and by internal criteria such as program balance, interactions with other functions, and staff capabilities.[8] Objectives for technical functions at Hewlett-Packard include the number of new products transferred to manufacturing and the breakeven times of these product development projects.[9]

A Focused Strategic Plan

The strategic plan should define the development path along which key capabilities will evolve. It translates the function's mission and objectives into short- and long-term goals and allocates resources. Authors have proposed several ways to articulate this plan:

Table 1	Identifying Posture and Setting Direction			
	Stage 1	**Stage 2**	**Stage 3**	**Stage 4**
Mission	• No mission statement	• Very general mission statement • Mission statement articulated but not communicated, understood, or accepted by staff or throughout business • Mission statement describes desired posture without substantive characterization of technical fields organization must master to sustain posture	• Common understanding within function but not throughout business • Portfolio of postures defined in relation to specific technologies and business strategy	• Shared understanding within function and throughout business • Differentiated by segment of value chain • Substantive characterization of core technologies and clear mission and posture with respect to each category • Long-term understanding of how technology can contribute to shaping business strategy
Objectives	• Not quantified • Not clearly tied to mission	• Purely internal — not tied to external points of comparison • Semiquantitative • Objectives related to specific projects	• Objectives defined in terms of the function's output • Proliferation of measures/objectives • Balance of short- and long-term measures	• Clear fit with business objectives • Sets direction for long term • Highly salient indicators of the function's output and processes • Interfunctional and intrafunctional indicators accepted within function and throughout business • Objectives include balancing the risk profiles of the project portfolio
Strategic Plan	• No plan, only a portfolio of projects • Plan formulated around current structure; driven by subunits' desires, not by mission	• Some focus within product lines • No interproduct line linkage • Inadequate information on longer-term customer needs • Defined for only one product generation	• Guides project prioritization within the function • Driven by business strategy • Defined for two product generations • Details how organization will realize objectives	• Fully integrated with other functions' plans • Substantive characterization of technology goals and tasks shared across business • Defined for three or more product generations • Specifies development path for product/process/support technologies • Clear criteria for make vs. buy vs.license-out • Involves worldwide sourcing of technologies • Facilitates building capabilities ahead of needs • Includes focused set of high-leverage initiatives

• As a mix of basic research, applied research, and development.[10] Clearly, however, this breakdown is insufficient; the organization needs to position itself at different places along this spectrum for its different technologies.
• As emphasizing product or process.[11] This distinction, too, must be handled carefully; the process must support the product focus and vice versa.
• As distinguishing between incremental and radical innovation.[12] Some authors use a two-dimensional matrix of technology newness and market newness.[13]
• As a question of compatibility and standards.[14] For example, the choice between "open" and proprietary architectures shapes TFS in many electronic equipment firms and among large-scale users.

A key challenge here is to characterize substantively the organization's high-priority technical domains. This is often difficult because technologists tend to define these domains in engineering and scientific terms, while people elsewhere in the organization think in terms of their own responsibilities. If technical managers want the other functions to buy in to their strategic plan, they must find a common language with their colleagues. This requires focusing on their technologies' competitively significant capabilities. Just by assessing these capabilities as base, key, pacing, or emerging, managers will have already created a knowledge base far superior to that of their typical competitor.[15]

A Stage 1 technical function does not have a strategic plan, only a set of projects, typically selected to meet short-term pressures from other functions. In a Stage 2 function the strategic plan gives direction for specific product lines but does not link product lines, does not go beyond the next project, and receives inadequate guidance from marketing and sales.

In contrast, a Stage 3 function's strategic plan clearly guides project prioritization based on the business strategy. It can guide decisions for at least two product generations into the future. Stage 4 strategic plans include important technology goals across the value chain. Stage 3 functions often overplan by creating a detailed itinerary of specific steps; Stage 4 functions define a longer-term "compass heading" that helps them respond to new opportunities that capitalize on their core capabilities.[16] Their strategic plans thus describe in broad contours three or even more product generations and articulate a clear policy on acquiring technology from external sources and licensing technology to external parties. The most distinctive feature of a Stage 4 strategic plan is its degree of integration with the other functions' strategic plans.

Raychem has an advanced approach. Its 1988 annual report lists fourteen core technologies that will be the basis for future products and systems and that will be key areas for developing new materials science capabilities.

At Pall Corporation, the world's leading specialty filter producer, the business and technical strategic plans are closely linked and mutually supportive. Pall participates only in markets where it can be amply rewarded for having the best technology. Its plans ensure that it can build capabilities before they are needed and transfer developments among areas, such as from electronic to biological applications.

Policies That Empower

We have found a surprising number of managers who, having defined their mission, objectives, and strategic plans, want immediately to select projects and action plans. They ignore the whole realm of policies and procedures, considering it inimical to technical creativity. But well-designed policies are empowering, not alienating, and employees appreciate how they guide day-to-day decision making. Well-designed policies need not impose a rigid bureaucratic mindset on the organization.

There is no one "right" list of policy areas that need articulation, but our experience suggests that the elements in Tables 2.1-2.3 need to be addressed. These policies cover three broad areas: (1) *processes* such as personnel recruitment, development and rewards, project selection, termination and management, and quality assurance (Table 2.1); (2) *resources,* which include intellectual property, funding, and facilities (Table 2.2); and (3) *linkages,* encompassing the function's structure, its interfaces with other functions, its linkages to external actors, and its approach to regulatory compliance (Table 2.3).

These tables summarize the common features we have found in a variety of settings. But an organization using this framework should define its own benchmarks based on its industry characteristics and competitive priorities. The hallmark of a Stage 4 function is consistency between the various policies, between the policies and the overall direction, and between the technical function's policies and those of other functions.

Personnel

While businesses vary in the degree to which they develop rather than hire personnel, no technical function can aspire to excellence without policies for both developing and capitalizing on its people's potential.

• **Recruitment.** In the most successful organizations, it is not uncommon for managers at the highest levels to spend a significant amount of time on recruitment. By contrast, in Stage 1 and 2 functions recruitment is typically passive and reactive. They do no planning, and they recruit on an ad hoc basis as openings develop. Stage 1 organizations typically confine their searches to the local area and tailor qualifications to whatever is available in this limited talent pool. Stage 2 organizations search a broader, multistate region but still balk at seeking the best talent nationwide.

Stage 3 functions plan for personnel needs at least three years ahead. They have an ongoing recruiting program that varies only modestly with the business cycle. They acquire a mix of new graduates and experienced personnel from a broad range of sources. To enhance the firm's reputation at selected universities, they provide summer student and faculty internships and present campus seminars.

Stage 4 functions have even longer-term recruiting plans (often on five-year horizons) for building capabilities, and they operate relatively independently of the business cycle. When appropriate, the recruiting program staffs international as well as domestic operations. Policies such as these account for the sustained recruitment success at AT&T's Bell Laboratories, Du Pont, General Electric, Hewlett-Packard, Merck, and Procter & Gamble. Stage 4 functions do not just aim at compliance with Equal Employment Opportunity requirements but positively value gender and racial diversity.

• **Development.** Personnel development should accomplish two objectives: to enhance individual career growth, and to maximize their contributions to the organization. But Stage 1 functions are typically so focused on short-term concerns that personnel development policies get little attention. Training and development programs either do not exist or are not funded adequately. Stage 2 functions have training programs, but they are limited to skill upgrading and unconnected to mission, objectives, and strategic plan. A career development program often exists on paper, but it is not well communicated, nor is it given high priority.

A Stage 3 unit has effective training and career development programs, including cross-functional transfers. Managers make hiring and promotion decisions based on long-term technology and business strategies. They make sure the company will have the appropriate mix of technical skills when needed.

A Stage 4 function has a long-term plan to build both technical and managerial skill bases. If it implements a dual ladder, it avoids the common problem of making the technical ladder a dumping ground. It reflects the increasing importance of global technology management in recruitment activities and development assignments. The unit promotes cross-functional transfers and encourages and rewards entrepreneurial behavior.

3M is justly famed for nurturing entrepreneurial actions and tolerating high-risk venture failures. Du Pont assigns high potential technical people to central R&D planning for two years to give them exposure to corporatewide programs and issues.

• **Evaluations and Rewards.** Effective reward policies meet two basic requirements: they are understood at all organizational levels, and they are administered consistently and fairly. Further, managers who evaluate technical professionals receive training and coaching.

As shown in Table 2.1, Stage 1 technical functions either do not have specific evaluation and reward policies or do not communicate them to lower levels. Personnel in these organizations often feel that political ties are more important than performance. They do not receive regular performance appraisals, and their appraisers may not have had any training.

Stage 2 functions usually have a formal system but lack rewards other than periodic salary increases. They do not distinguish meaningfully between performance levels, and they often use inappropriate formulae to determine salary increases. Management does not communicate the reward system's logic to staff below supervisor level.

Stage 3 functions have formal policies and explain them to all employees. The rewards may include special recognition for exceptional performance. Supervisors and managers receive training and give their subordinates a full appraisal at least annually. Rewards are linked to demonstrated performance and to forecasted future performance.

Stage 4 units mix individual and team rewards and have innovative approaches for motivating personnel. They publicize rewards and may involve senior managers in their presentation. Managers' contributions to personnel development are considered when their future potential is evaluated.

Technical Projects

• **Selection and Termination.** Project selection and termination are among the most difficult decisions that technical managers face. Organizational culture, resource constraints, short-term pressures from both internal and external customers, and career aspirations are only a few of the factors that unduly influence what should be a predominantly rational process. While none of the many analytic models that have been proposed for managing this process is demonstrably superior, some decision criteria do seem to correlate with effective programs. They involve using relevant information on markets, customer needs, competitors, and regulatory and environmental concerns. Also crucial is linking resource allocation decisions with the function's mission, objectives, and strategic plan.

Stage 1 and 2 technical functions tend to favor short-term projects. They give little if any consideration to strategic factors such as exploiting inter-product-line synergy. Stage 3 and 4 organizations seek a project portfolio that balances long-term strategic objectives with current needs. They routinely allocate resources to maintaining skill bases and developing core technologies and new tools for improving technical productivity. These functions undertake low-cost feasibility probes before making major commitments. They also consider all the resources needed from R&D to commercialization, in order to avoid projects whose technical promise obscures a low

Table 2.1 Policies That Empower: Processes

	Stage 1	Stage 2	Stage 3	Stage 4
Personnel: Recruitment, Development, Evaluation, and Rewards	• Recruit only for specific openings • Recruit only from local area • No training or development programs • Rewards based on who you know; favors most senior-level people • No support to first-line supervision in evaluation process	• Recruit locally and regionally • Training programs unrelated to strategy needs • Limited communication on reward system • No significant difference in monetary rewards for different performance levels • No meaningful rewards other than salary increases	• Active nationwide college recruiting • Career development programs • Training at all levels • Three-year personnel plan • Cross-functional development • Realistic appraisals • Appraisal training • Written evaluations, annual reviews • Significant differences in rewards for top performers	• Recruiting based on skill mix, competency analysis, and long-term staff development planning • All management levels involved in selection • Effective dual ladders • Recruitment and development recognize need for global technology management • Planned balance of roles • Incentives for entrepreneurial behavior • Interfunctional and international career opportunities • Mix of individual and team rewards • Personnel development accomplishments a key factor in evaluation of managers
Technical Projects: Selection, Termination, and Project Management	• Favors short-term projects • Politically driven selection • No project monitoring or preproject planning • Little interfunctional participation in project teams • Erratic turnover of team staffing • Project leader roles not defined • No training for project leaders • Unclear charters for project teams	• Mix of short- and medium-term projects • No inter-product-line analysis • Priorities set erratically • Project tracking • Some interfunctional participation but not all key functions are represented • Formal release process for new products • Some project team stability but conflicts over work priorities • Project leaders given only minimum guidance or training	• Selection based on multiple inputs from internal and external sources • Balance of short-, medium-, and long-term projects • Risk analysis incorporated at key phases • Projects still schedule driven • Interfunctional project teams wherever needed • Clear allocation of project and functional responsibilities • Training for project leaders	• Clear links between selection criteria and business and product-line strategy • Disciplined process for project termination • Cross-functional planning and execution • Continual improvement—postmortems, quality measures of both project process and product performance • Projects are milestone driven • Differentiated project management procedures for different types of projects • Scheduling and capacity planning avoid resource contention by competing projects
Quality Assurance	• No quality measures • Finger-pointing	• Controlled output quality, some design quality measures • Problems fixed as they arise	• Checkpoints for in-process quality control during development process • Root cause analysis of quality problems • Focus on satisfying internal and external customer needs	• Detailed process models and metrics for all routine technical operations; continuous improvement • QFD-type methodologies used routinely to assure customer perspective

probability of commercial success. To help ensure that initiated projects do not develop a life of their own, General Electric, Monsanto, and Texas Instruments all use an annual zero-based budgeting approach.

Terminating projects is frequently more difficult than selecting them. The most advanced organizations have a disciplined review process for termination candidates. At GE's Corporate Research Laboratory, for example, senior managers review projects in question intensively; outside consultants may also participate. New product development projects at Xerox's Corporate Research Group are subjected to regular appraisal based on inputs from marketing and strategic planning.[17]

• **Project Management.** Stage 1 functions do not clearly define the project managers' roles or the teams' objectives and responsibilities. Project teams often form only after considerable vacillation. Preproject planning is limited. Stage 1 organizations rarely develop formal project plans or regular reports on project status. Politics often drives staffing decisions, and project managers may be appointed without any training. Interfunctional communication is minimal as projects move from R&D toward commercialization. Project monitoring is either nonexistent or intermittent.

Stage 2 functions have formal project management charters and specified planning and monitoring systems. Project teams have some interfunctional participation, but some "low status" functions may still be ignored. Manufacturing often joins the project team only after the product has been defined. While the function usually has a formal handoff process, team members bicker over whether the product is ready for transfer. Project staffing is more stable than in Stage 1, but conflicts persist between project managers and functional managers over resources. Project managers are usually experienced, but they may lack formal training for this difficult role. Lack of analysis or inadequate communication from senior management make priorities within and between projects unclear.

Stage 3 technical units base project priorities on a clearly articulated, long-term business strategy. Senior managers ensure that projects receive adequate resources, consistent with these priorities. Consequently, resource conflicts are minimized. The project team includes representatives from all key functions, and it has the authority to make appropriate decisions. Formal handoffs are unnecessary because the team has full responsibility for all project stages. Risk analysis and contingency planning are standard practice. Project objectives and product-process specifications are adjusted to meet market changes.

In Stage 4 project management, technologies are developed and proven before being incorporated into new projects. These functions conduct project postmortems and incorporate their learning into future project planning. "Simultaneous engineering" brings all the key functions and major suppliers into projects and reduces time to commercialization. Each project is linked to long-term business strategy, which includes a multiyear "map" of successive generations of products and processes. Managers consider potential competitor reactions to product introductions. Team members work with anticipated users to meet the market's needs. Fast time-to-market is assured not by long overtime hours but by appropriate scheduling and capacity planning. One of a Stage 4 technical function's key strengths is its ability to minimize resource contention across multiple projects. Managers monitor project milestones and take prompt corrective actions — even for project termination. Detailed progress reports and reviews are minimized to allow project managers to focus on key issues.

Xerox of the 1980s had a Stage 4 approach to project management. According to Jacobson and Hillkirk:

> *Instead of . . . manufacturing and service engineers checking on design engineers, everyone protecting their turf, and no one with absolute responsibility to get the product out, Xerox created, with the business units, what it calls product delivery teams for each new machine. Each team is made as self-sufficient as possible. . . . The chief engineer is given a set of boundary conditions. If he stays within the cost and schedule targets there is no need for a review.*[18]

Quality Assurance

Traditional approaches emphasized quality of *output* rather than *process* quality. But manufacturing's zeal for building quality into its processes is spreading to technical operations.

Stage 1 and 2 organizations give lip service to quality issues but often execute quality programs ineffectively. If quality problems arise, they typically appoint a task force, but it neither finds underlying causes nor proposes long-range solutions. They think, "Quality personnel will produce quality work, so why change the work process?"

Stage 3 organizations understand that quality depends more on process than on individuals. The quality assurance department analyzes root causes of problems, and the function incorporates the recommendations into its processes.

Stage 4 organizations mobilize the entire technical workforce to continuously improve quality. Technical operations are well documented, and routine tasks are standardized in order to define key quality metrics, such as the average number of prototype iterations. Tools such as Quality Function Deployment (QFD) help managers interpret quality from the customer's point of view.[19]

Quality management is one of the major improvement opportunities for technical functions. We believe

Table 2.2 Policies That Empower: Resources

	Stage 1	Stage 2	Stage 3	Stage 4
Intellectual Property	• Ignored	• Rewards for patents • Intellectual property issues left to the legal department	• Selective patenting based on evaluation of pros and cons of disclosure • In-licensing if needed and outlicensing if asked • Trade secrets defended in court	• Intellectual property opportunities are part of business strategy, project selection, and project management criteria • In-licensing to maintain focus, speed, external point of comparison, and learning opportunities • Technical personnel rotate through intellectual property department • Out-licensing based on business and technical assessments • Comprehensive trade-secret policies that avoid paranoia
Funding	• Last year plus inflation minus business's cash flow delta or "gut feeling"	• Industry average levels	• Supports development of new productivity tools • Maintains and develops skill base	• Flexible, related to potential business contribution over short and long term • Minimal fluctuations despite cash flow variation • Mix of corporate tax, internal contracts, and external contracts • Budget approved for three years out
Facilities and Equipment	• Outdated facilities and equipment • Fad acquisitions • No training costs budgeted • Limited by fixed capital allocation	• Equipment acquisitions justified by labor savings but not strategic importance • Facilities design and staffing done without considering communication • Poorly designed and overly bureaucratic access and utilization policies	• Detailed implementation planning • Training included in equipment budgets • Justification includes long-term and intangible benefits • Willingness to support experimentation	• Builds ahead of demand • Competitive advantage factored into selection • Vendors help develop new tools • Facilities enhance communications • Open access policies

that Crosby's "quality is free" argument for manufacturing also applies to new product development.[20] Quality does not have to take longer or cost more. Technical functions can reduce costs and accelerate projects by improving the quality of their internal operations.

Intellectual Property

We shift now from process policies to resources, of which intellectual property is key for the technical function (see Table 2.2). The Federal Circuit Court of Appeals, created in 1982, has greatly strengthened the temporary monopoly afforded by patents. However, most companies are still stuck at Stage 1 or 2 in their treatment of intellectual property policies; they either ignore them or delegate patent filing to legal technicians. Senior managers only notice this issue when a key employee makes off with the "crown jewels." When eight executives left Motorola's semiconductor division in 1968 to join one of its key competitors, Fairchild, the court denied Motorola any relief because the company had not taken reasonable steps to protect its trade secrets.[21] Motorola has since formulated comprehensive policies in this domain.

Stage 3 and 4 functions consider intellectual property issues at key decision points. They evaluate patent opportunities in terms of long-range business and technical strategies. Stage 3 organizations quickly identify intellectual property opportunities as projects develop; Stage 4 organizations also consider intellectual property issues in project selection. Stage 4 functions make sure that in-licensing and out-licensing policies support the overall strategy.

3M has advanced intellectual property policies. It provides extensive training and includes intellectual property management in performance appraisals. Lab directors are responsible for monitoring and improving the value of their intellectual property portfolios. Business unit general managers are expected to have a strategic patent plan, which is assessed periodically by corporate staff.

Funding

Stage 1 and 2 technical functions usually base their budgets on the prior year, adjusting for inflation and possibly for sales or profit changes. The funding level tends to be at or below the industry average. Seldom do they adjust funding to meet new demands or opportunities.

Stage 3 and 4 organizations fund technology developments based on both strategic considerations and current needs. They avoid funding level fluctuations, particularly decreases. When a major new thrust requires significant and sustained resources, they will make long-term commitments, sometimes up to three years.

Du Pont and Monsanto, for example, have committed resources to biotechnology over multiyear budget cycles. Some companies, including General Electric, Westinghouse, and TRW, secure funding from both internal and external sources, such as government contracts, to reduce net R&D costs and to buffer changes in annual budgets.

Facilities and Equipment

Stage 1 and 2 functions often have outdated facilities and equipment and do not use new ones effectively. They justify equipment purchases on the basis of labor savings, but they give strategic considerations low priority. The operating budget includes minimal resources for training. Policies covering facility use are bureaucratic and discourage night and weekend work.

Stage 3 and 4 functions consider both short-term cost advantages and long-term strategic and intangible benefits. They provide training and design facilities and support equipment to enhance communications between groups. Facilities are constructed and equipment purchased before shortages interfere with productivity. The staff works closely with vendors and other technology sources, such as universities, to develop and test new tools. And use policies are convenient for users. One day in 1959, William Hewlett, cofounder of Hewlett-Packard, could not get a microscope because the storeroom was locked after normal working hours. He told the clerk in charge never to lock the storeroom again — it was worse to stifle technological development than to risk theft. Today Hewlett-Packard keeps its laboratories and storerooms open around the clock.

Structure

Of the linkage policies, those governing the structure of the technical function itself are clearly fundamental (see Table 2.3). Organizational structure issues include (1) how structure will affect communications within and outside the technology function; (2) how much centralization is desired; and (3) how projects will be planned, staffed, initiated, and managed. Ideally, the structure should facilitate achievement of short- and long-term objectives. In practice, organizational history, management style, and business constraints may produce a suboptimal structure.

Research has demonstrated that personal contacts between technical personnel decline rapidly as the physical distance between them increases.[22] Although new technologies such as video conferencing and electronic mail may mitigate the negative effects of geographical separation, the nature of technical tasks often requires direct and frequent personal interaction.

Putting people who need to work closely together in different units with different reporting relationships may also reduce effectiveness. When organizational and geographical barriers are combined, the development and transfer of technology is significantly hindered. AT&T's Bell Laboratories and its Western Electric manufacturing subsidiary developed an approach based on the principle that a geographical *barrier* required an organizational *bond* and vice versa; both barriers should not occur at the same time.[23]

Stage 1 and 2 units tend to be organized functionally with centralized authority. If they are decentralized, political conflicts or turf battles, rather than rational analysis, often shape the resulting structure.

Stage 3 and 4 functions tend to be matrix rather than centralized and functional organizations. They consider communications patterns and working relationships, and they often establish temporary structures to achieve key goals. At Allegheny Ludlum, a leading specialty steel producer, approximately two-thirds of the technical staff works in the firm's factories instead of in isolated laboratories. Manufacturing methods improve concurrently with new product development, hastening commercialization and reducing production problems.

In Stage 4 organizations, the structure is designed to encourage the unexpected. Hewlett-Packard promotes

Table 2.3 Policies That Empower: Linkages

	Stage 1	Stage 2	Stage 3	Stage 4
Structure	• Functional organization • Centralized authority • Acceptance of status quo	• Some decentralization by business unit or geography • Structure shaped primarily by ego/political conflict rather than strategic priorities	• Matrix where needed • Reflects strategic priorities • Shaped by concern with communications and meeting goals	• Optimizes communications and achievement of strategic objectives • Flexible enough to support and promote initiative and entrepreneurship
Interfunctional Linkages	• Visible friction • Mistrust of functions	• "We/they" syndrome • Cooperation at top or at operational level but not both • No effective bridging mechanisms	• Interfunctional task forces to facilitate joint efforts • Mutual cross-functional respect	• Multiskilling of specialists, awareness and respect of other functions developed by systematic cross-functional assignments, and job rotation • Joint development efforts across functional subunits
External Linkages	• "Not invented here" syndrome • Secrecy	• Relationships with local universities, some vendors • Participation in trade associations • Some regular customer contacts • Little external technology sourcing	• Clear make vs. buy decision criteria • Clear partnership policies • Close relationships with leading vendors and customers • Moderate amount of external linkage but restricted to U.S. • Ongoing contacts with universities, government agencies, industry consortia, etc.	• Information sharing upstream, downstream, and in collaborative worldwide industry relations • Sourcing policies strengthen core technologies and build new ones • Ongoing marketing of unrelated innovations
Regulatory Compliance	• No policies • No controls • "Get by with what you can"	• Formal policies • Compliance enforced by corporate audits • Passive general management	• Thorough training of all employees • Active publicity campaigns to promote compliance • Cordial relationships with community leaders and regulatory officials	• Proactive, anticipates trends • Line responsibility for compliance • Products and processes designed to minimize environmental impact and health and safety hazards

cross-fertilization of scientific disciplines in order to develop technologies for new markets. For example, it combines specialists in sensors, analytical chemistry, and electronics to develop new medical instruments. Similarly, 3M forms small business development teams to consider promising business opportunities.

Interfunctional Relationships

Lack of cooperation and goodwill between functions can delay or thwart new technology development. Relationships between R&D and manufacturing and marketing are usually the most troublesome, but similar tensions can develop between manufacturing engineering and manufacturing operations, and between MIS and its internal clients. Differences in personal values and career orientations often cause these problems. Thus policies that promote interfunctional collaboration must be complemented by other policies, such as those governing training and organizational structures, and by coordination of missions, objectives, and strategic plans across all functions.

Stage 1 and 2 technical functions often seriously conflict with other key functions. Technical managers mistrust the motives of personnel in other functions and transfer these attitudes to lower levels. Stage 2 organizations promote better relationships but lack bridging mechanisms.

Stage 3 functions develop policies for reducing interfunctional barriers such as joint goalsetting and the use of multifunctional task forces. Stage 4 organizations such as IBM and Hewlett-Packard go a step further by using systematic temporary cross-functional assignments as well as encouraging transfers among functions. The leaders of these functions both teach and practice understanding of the cultures, constraints, and goals of the other major functions.

Another important challenge in multidivisional firms is collaboration across divisions. Many firms manage poorly the relations between corporate R&D and the divisional technical functions, as well as those between the technical functions across divisions. Job rotation and organizational forums that bring these groups together for informal knowledge sharing are critical to long-run effectiveness.

External Linkages

In the last decade, successful companies have dramatically changed their relationships with external organizations. Firms such as IBM, General Electric, and Eastman Kodak have pursued different approaches for acquiring and exploiting new technological capabilities, including acquisitions, mergers, strategic alliances, industry consortia, and joint developments with universities or government laboratories.

Japanese firms have built strong market positions based on licensed technology, and this has spurred others to consider external sourcing as an alternative or supplement to internal development.[24] Many technological fields are developing so rapidly on a global basis that no single firm has the resources or time to investigate all of the potentially relevant technologies. These developments are eliminating some of the not-invented-here syndrome that focuses organizations solely on internal developments.

In addition, vendors and customers at the forefront of technological developments can provide product ideas and other important information. AMP is one company that has effectively used its customers to guide its product development programs. The company's 1988 annual report notes, "Nearly all of our products have arisen out of 'early involvement' programs with customers who are technology leaders in their fields. This is a pragmatic process based on customer inputs at each stage of defining requirements, developing and testing prototypes, creating a final design, and committing to product tooling."

In contrast, Stage 1 functions have limited contact with customers and vendors. They talk to customers' purchasing agents rather than technical and marketing personnel. Stage 2 functions have more contacts, which might include vendors and local universities, and interact with them more frequently. However, such relationships are not managed to secure strategic advantages.

Stage 3 and 4 technical functions consider external linkages an integral part of their strategy. They initiate and maintain contacts with universities, government agencies and laboratories, industry consortia, licensing organizations, and other sources. Furthermore, they share information upstream with vendors and downstream with customers. At the most advanced stage, each arrangement is part of an overall strategy for enhancing the firm's technical and business positions. Such organizations regularly consider the pros and cons of internal and external technology development, and they have clear decision criteria. Specific policies govern alliances and partnerships. They are not too proud to commercialize products based on acquired technologies. Technologists have direct and regular contact with customers. At Chaparral Steel, an innovative, highly profitable steel company, shop-floor teams visit equipment vendors, customers, and competitors all over the world. Similarly, Allegheny Ludlum encourages its marketing and technical personnel to visit customer firms' engineers to learn about future needs. Pall has over 350 Ph.D.'s who link customers and marketing with the R&D organization.

> Stage 4 functions benchmark internal processes as well as products, and they seek out the best practices in any industry.

Regulatory Compliance

Regulatory compliance and protection of worker and community environments are becoming increasingly important business issues. Stage 1 organizations, however, see compliance as a hindrance to getting work done; managers and employees "get away with" what they can. Stage 2 units have formal policies and periodically assess compliance, but management does not take an active role to ensure that both the spirit and the letter of policies are followed.

Stage 3 units use internal publicity to promote regulatory compliance, and they do not permit shortcuts. Employees are trained to recognize and handle environmental issues and receive appropriate recognition for innovative solutions. Managers maintain cordial, open relationships with community leaders and regulators.

Stage 4 functions deal proactively with personnel, environmental, health, and safety regulations. Community and regulatory officials value their expertise. Such organizations establish long-term goals and intermediate milestones and then closely monitor progress. As standard practice, products and processes are designed to minimize environmental impact. Line managers and supervisors have compliance responsibility and are rewarded or penalized appropriately.

Responsive Adjustment Mechanisms

Critical to a technical function's success is its ability to learn — to adjust its mission, objectives, strategic plan, and policies in light of experience. Table 3 identifies some common features of these adjustment processes in more and less effective organizations.

Assessing Strengths and Weaknesses

Stage 1 functions usually have no programs to assess their technical strengths and weaknesses, let alone the ability to relate findings to the business's needs. Some individual projects may be informally assessed, but not within a broader context.

Stage 2 technical units make a modest effort to compare subunits with each other and with domestic competitors. However, these analyses typically focus on headcount or funding levels, not the functions' competency base. Moreover, Stage 2 functions typically do not assess foreign competitors' capabilities or monitor changes in competitors' capabilities over time.

Stage 3 organizations systematically assess their capabilities for meeting their markets' requirements. These assessments cover the same horizon as the business strategies, usually about three years, and they usually include foreign competitors.

Stage 4 organizations not only assess their core technologies' strengths and weaknesses against frontier technologies, they also consider source sciences and related technologies. The time frame may extend beyond the business strategy horizon because building strong capabilities in new areas may take ten years or longer. For example, many firms have found that becoming proficient in molecular biology and genetic engineering takes at least ten years. Stage 4 firms also track potential competitors and assess their current and future capabilities.

Benchmarking is an invaluable technique in these assessments. But while Stage 3 organizations focus on the best products in their own industry, Stage 4 functions benchmark internal processes as well as products, and they seek out the best practices in any industry. Xerox compares its engineering practices against the best practices worldwide, not just in the photocopier business.[25] The company discovered valuable lessons in materials storage and retrieval technology at L.L. Bean.

Assessing Opportunities and Threats

As businesses compete, they create new opportunities for, and threats to, each other. Many technical units fail to rise above day-to-day concerns to look at the whole, dynamic market. Stage 1 technical functions simply react; they have no formal assessment process. They receive little useful feedback from the business's commercial side, and they ignore external developments.

Stage 2 technical functions typically do some market assessments and forecasts, but they do not work with planning, marketing, and sales. They ignore industry trends outside their own product lines. This was the pattern at Wang, when the technical and commercial functions apparently failed to assess the serious threat posed by microcomputers in fields traditionally dominated by minicomputers.

By contrast, Stage 3 technical organizations systematically analyze competitors' actions and market changes to pick up advance signals of opportunities and threats. Such organizations have formal mechanisms for getting information from planning, marketing, and sales. They also routinely review technical and trade publications (sometimes supplemented by recourse to outside scanning services), and attend technical and industry meetings. Changes in societal attitudes, legislation, and regulations are also monitored.

Stage 4 functions go even further by actively exploring opportunities with customers, suppliers, governmental agencies, and other sources. They sometimes enter into strategic alliances specifically to ensure continual exploration. Du Pont has done this, establishing alliances in such fields as disease diagnostics, therapy products, and high-temperature superconductors.

Using the TFS Framework

Is this framework exhaustive? Clearly not. First, it focuses on strategy and therefore leaves out important issues such as organizational culture.[26] But we believe that an effective TFS is a key element in using technology for competitive advantage.

Second, it focuses on the strategy *process* — the "hows" of formulating and implementing TFS — rather than on specific *content* — the "whats" that are most appropriate to each organization. While content naturally preoccupies most functional managers, process is just as important because it guides the organization systematically toward appropriate content decisions.

We have suggested some guidelines for assessing individual elements of the strategy process. To use this framework successfully, you must synthesize your assessment of the individual elements into an overall assessment, and then you must draw some actionable conclusions.

In our experience, the assessment process is exciting. People articulate concerns and suggestions, reviewing both day-to-day operations and longer-term trends. The process creates a forum for forging a powerful consensus on future directions.

The process will be most effective if you create a rather broad working group. The group should include the entire technical function's management team, and you may want to include some key "internal customers" from other functions. It may even be desirable to bring together a vertical cross-section of the technical function — this can be a powerful way to build strategic thinking into the organization's lower levels.

We recommend that the working group proceed in five steps:

1. Review the list of TFS elements and tailor them to your organization's needs.

2. Review our characterizations of the four stages on each element — they may differ for your industry or your organization's strategy. Conduct your own research to build characterizations of the four stages that capture your critical issues. The essential thing is that your working group feel committed to the assessment criteria.

3. Assess your technical organization on each element. Be as objective as possible. Visit other organizations, collect data, analyze documents, and conduct surveys if necessary.

4. Identify improvement priorities and impediments to making those improvements. In many cases, this step is the one with the highest yield; it forces the organization to understand the origin of the current weaknesses. In

Table 3 Adjustment Mechanisms

	Stage 1	Stage 2	Stage 3	Stage 4
Strengths and Weaknesses (S/W)	• No ongoing assessment • Project by project assessment • No forecasting	• Assessments based on organization chart rather than product requirements • Some assessments of leading domestic competitors' capabilities but based on headcount and funding levels • One-year time horizon • Some technology forecasting	• Assessments based on product requirements • Same horizon as business strategy (usually three years) • Detailed assessment of technical capabilities of current competitors worldwide, systematic product benchmarking	• Assessments based on distinctive competencies that link source sciences/generic technologies and evolving product and market O/T • Assessments of technical capabilities and technology management processes; benchmarking of products and processes • Longer time horizon: five–fifteen years • Assessments of technical requirements for all major technology areas: product, process, and support • Assessments of potential as well as current competition
Opportunities and Threats (O/T)	• Reactive • Little feedback from field	• Weak link to product planning • Weak input from field engineering and sales/marketing • Narrow focus on current products and technologies	• Systematic scanning of competition, markets, societal trends, etc. • Dialogue with field engineering and sales/marketing • Resources for analyzing the O/T data • Routine updates on O/T throughout function	• Active exploration of O/Ts with customers, suppliers, universities, government agencies, and rivals • Analysis of how market trends and competitors' strategies will affect future projects • Analysis of potential effects of political, economic, social, and demographic changes

an ideal world, every technical organization would aspire to Stage 4 on all elements. But in practice, getting to Stage 4 takes time and effort. Given scarce resources, managers need to decide where to focus their improvement efforts. Indeed, improvement efforts in the technical function may have to compete for resources against improvement efforts in other functions. The working group therefore needs to balance the improvement benefits against the associated costs.

5. Formulate appropriate action plans, ones that ensure that goals are reached by tackling the relevant impediments and leveraging available resources.

When isn't this approach likely to be useful? Our experience suggests that it will not prove very effective when the company's critical success factor is the accuracy of the intuition of a single technical guru. This approach may therefore not be very useful when the organization is small and less mature.

Can this framework be applied in technical functions other than product development? Our experience suggests that it can easily be adapted to basic research departments and to MIS and manufacturing engineering functions. We have even found an appropriately modified version useful in working with human resource functions. Whenever a functional department wants to manage its capability development more strategically, it will need to address the kinds of questions suggested by this framework.

Whether technology plays a supporting role or is the business's basis of competition, the technical function manager has the responsibility to provide maximum value for the resources invested. Our TFS framework does not provide a magic recipe or even an exhaustive list of success factors. But it provides a platform for improving the function's contribution to business success.◆

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