Regular Paper

Strategies for Value: Quality, Productivity, and Innovation in R&D/Technology Organizations

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Received October 23, 2000; Accepted December 21, 2000

ABSTRACT

The nature of value and how R&D/technology organizations provide value are considered. Value is defined in terms of three dimensions: quality, productivity, and innovation. This framework provides the basis for formulation of value strategies in terms of where value is to be provided, how it will be provided, enterprise designs that support these intentions, benchmarking to identify gaps, and specification of action plans. Implementation of value strategies is discussed relative to strategies for change, multistage decision processes, organizational implications, balanced scorecards, and adaptation of strategies to different types of enterprises. Illustrations of multistage decision criteria and balanced scorecards for R&D/technology organizations are provided. © 2001 John Wiley & Sons, Inc. Syst Eng 4: 87–106, 2001

1. INTRODUCTION

R&D/technology organizations[1] have faced considerable pressures in recent years [Roussel, Saad, and

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Systems Engineernig, Vol. 4, No. 2, 2001

[1] Many enterprises do not have organizational entities labeled R&D. Instead, they choose to call this function technology development or something similar, avoiding the word "research." This article is intended to address the concerns associated with R&D functions regardless of whether the enterprise uses this term. Hence, the phrase R&D/technology is employed.

Erickson, 1991; Matheson and Matheson, 1998; Miller and Morris, 1999; Rouse and Boff, 1998, 1999; Rouse, 2000a]. This has included increasing accountability for delivering value to the enterprise. R&D/technology investments are decreasingly based on "faith." There is also much greater emphasis on organizational linkages and transitions of value from R&D/technology organizations to product lines, operational units, etc. Further, there is much less tolerance for *unmanaged* risks and uncertainties, which has increased emphasis on understanding, anticipating, and managing both technical and application risks.

Focusing on value inherently begs the question of who is to be provided value. For most large organizations—regardless of whether for-profit, nonprofit, or public sector—there are numerous types of stakeholders or constituencies for whom value is to be provided. Further, different stakeholders have different preferences and priorities. Not infrequently, the various preferences and priorities are in conflict, at least in the sense that they compete for the same limited resources.

More specifically, in the private sector shareholders seek earnings and growth, and consequently increasing share prices. Customers want quality products and services at reasonable prices. Employees desire meaningful jobs, stability, and personal growth. The public is focused on defense, health, safety, and so on. Seldom is it the case that all these stakeholders can be completely satisfied. Consequently, tradeoffs across stakeholders' interests are inherent. Developing a value strategy involves addressing these tradeoffs. The resulting strategy embodies the resolution of the tradeoffs.

This article considers the nature of value and how organizations provide value. Value is defined in terms of three dimensions: quality, productivity, and innovation. This framework provides the basis for formulating and implementing value strategies in terms of strategies for change, multistage decision processes, organizational implications, balanced scorecards, and adaptation of strategies to different contexts. These discussions are all pursued in the context of R&D/technology organizations, with particular emphasis on nonprofit and public sector R&D organizations.

The framework presented in this article fits within a systems-oriented view of management in at least two ways. First, many R&D/technology activities often occur within systems functions, and this framework can support enhancing the value of these activities. Second, and perhaps much more important, this framework reflects the application of systems-oriented thinking to design of processes and organizations to enhance the provision of value.

2. NATURE OF VALUE AND VALUE STREAMS

Value is defined by the *Merriam-Webster Collegiate Dictionary* as relative worth, utility, or importance; the monetary worth of something, i.e., its marketable price; and a fair return or equivalent in goods, services, or money for something exchanged. These definitions are compatible with the use of this term in this article.

Beyond defining value, it is important to describe the characteristics of value as provided by organizations:

- Value focuses on organizational outputs (or outcomes), rather than inputs—an organization's budget (an input) may reflect the value the organization provides, but it is not a direct measure of this value.
- Value relates to the benefits of organizational outcomes, rather than the outcomes themselves—while data, methods, and tools may be the outcomes, benefits typically concern what these outcomes enable.
- Value implies relevance, usability, and usefulness—these attributes of outcomes are ultimately assessed by the beneficiaries of the organization's outcomes rather than those who create these outcomes.

Enhancing value requires consideration of the processes whereby value is provided to stakeholders. Typical processes for manufacturing companies are business capture,[2] product development, product build, and product support. For R&D/technology organizations, processes may include opportunity/need identification, approach/concept formulation, R&D execution, and technology transition.

2.1. Value Streams

The flows of value added by processes are sometimes termed value streams. Understanding and managing these value streams involves assessing how current processes do or do not add value, and redesigning processes to insure that the value/cost proposition for each process makes sense [Womack and Jones, 1996]. Assessment and redesign usually lead to reallocations of resources to activities and projects that will enhance value.

A central issue in consideration of value streams, or more broadly value chains, concerns the distinction

[2] This typically involves functions such as marketing and sales, but is usually much broader in the sense of including all aspects of attracting customers, making sales, and assuring customer satisfaction.

between the next user and the end user [Boff, 2000]. The end user may be the ultimate customer and beneficiary of the value being created. However, value usually has to be provided to intermediate users if they are to able to add value. For example, technologists must provide data and documentation to designers if they, in turn, are to be able to implement technologies successfully in new products. Excessive focus on only the end user can create dysfunctional value streams.

It is important to emphasis the fundamental role this distinction plays in formulating and implementing a successful value strategy. Understanding the series of users in the enterprise's value streams has been found to be essential to enhancing the flow of value in these streams. To the extent that the next user is ignored due to preoccupation with end users, the effectiveness of the overall value stream is compromised, somewhat ironically undermining abilities to provide value to end users.

2.2. Value Tradeoffs

Understanding value includes assessing and projecting the value of products and processes, including tradeoffs across economic and noneconomic impacts of alternatives. Such tradeoffs are often complicated by the multistakeholder, multiattribute nature of value in most organizations. For example, particularly in nonprofit and public sector enterprises, one or more stakeholders may value a process despite the fact that this process does not contribute to—or possibly detracts from—the value embodied in the enterprise's products. Cost/benefit models and methodologies for addressing this complexity can be central to making investment decisions [Rouse and Boff, 1999].

The concept of value is further complicated by the evolving nature of stakeholders' issues, concerns, and preferences, which tend to be strongly affected by external trends and events related to technology, economics, and politics. For many types of organizations, intentions and actions of competitors can also affect stakeholders' preferences. An organization's value strategy should anticipate such changes, and its R&D portfolio should reflect this strategy.

Slywotsky [1996] uses "value migration" to characterize the evolving nature of value. He emphasizes the need to recognize how value changes in terms of priorities, time horizons, willingness/abilities to pay, etc., and adapt products and services to take advantage and minimize risks of these changes. This requires that R&D organizations create the technology options needed to enable subsequent exercising of these options in this process of adapting value strategies and market offerings.

Beyond adopting an overarching goal of providing more value to stakeholders, an enterprise's value strategy needs to address specifically how value is to be enhanced. There are several dimensions along which value enhancements should be pursued. The next section elaborates these dimensions.

3. QUALITY, PRODUCTIVITY, AND INNOVATION

Figure 1 portrays three dimensions of value strategies. Quality traditionally relates to the reliability, fit, and finish, etc. of products and responsiveness, friendliness, etc. of services. Productivity concerns efficient use of resources that enables lower costs and attractive prices. Innovation deals with the extent to which offerings provide new and possibly unique benefits. Focusing on value in the context of R&D/technology organizations requires rethinking these traditional definitions and tailoring them to this context. Further tailoring is needed for nonprofit and public sector organizations.

The choice of the dimensions of quality, productivity, and innovation was driven by the recognition that debates surrounding organizational improvement and change initiatives often encounter intellectual baggage from past attempts to implement hoped-for panaceas for all problems. Total Quality Management (quality), Business Process Reengineering (productivity), and Knowledge Management (innovation) have successively been candidate panaceas, all eventually leading to disappointments.

However, all three of these constructs have substantial merits when viewed as elements of an overarching and more integrated approach to improvement and change. The debates, therefore, should not be about which of these constructs to employ, but instead how best to integrate the three perspectives relative to the goal of providing value to stakeholders. From this perspective, one goal of this article is to encourage the right debates.

3.1. Value Strategies

Formulation of a value strategy can be viewed as defining a desired position in the "value space" defined by Figure 1, assessing the current position, determining gaps between "to be" and "as is," and defining an action plan for closing gaps. More broadly, a value strategy can be viewed as a portfolio of positions in the value space.

In many cases, the most attractive value strategy will be to provide superior quality, highly innovative offerings, with excellent productivity and hence substantial

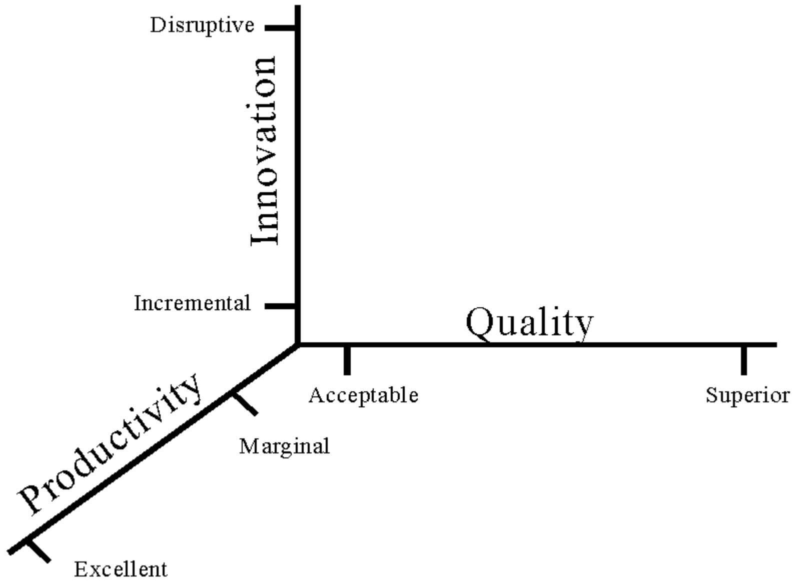

Figure 1. Three dimensions of value strategies.

profit margins or equivalent metrics.[3] However, often this combination is not possible. More common is a strategy to provide expected quality (or better), at competitive costs (or prices) relative to the innovative characteristics of products and services.

Another possible strategy incorporates undifferentiated quality and innovation, matched with low prices. This obviously requires high productivity to assure profits. Yet another possible strategy pursues at least benchmark quality and innovation, matched with "value pricing" that reflects the extent to which benchmarks are significantly exceeded.

There are numerous examples of enterprises employing variations of these strategies. BMW and Lexus focus on superior quality and innovation, and do not enhance productivity to the detriment of these dimensions.. Honda Accords and Toyota Camry provide a balance across all three dimensions. Low-end offerings by Ford and General Motors address the most price-sensitive automobile customers, and hence productivity (i.e., person-hours per vehicle) is a driving force.

Examples of these value strategies within R&D/technology organizations are more difficult to provide, in part because such strategies usually cannot be publicly divulged. More to the point, however, is the simple fact that the value-oriented thinking outlined here has only recently been systematically applied to R&D/technology organizations as they have been pressured to show how they add value to the overall enterprise. This article is intended to support making this case.

The foregoing notions of value strategies must be modified for nonprofit and public sector enterprises where value tends to be somewhat more subtle. Health-related nonprofit organizations, for example, are judged by the percentage of donated resources applied to the organization's mission, e.g., fighting cancer, and the effectiveness of these investments in creating desired outcomes—prevention, detection, and treatment of disease, as well as enhanced quality of life for patients and families [Rouse, 2000b].

Nonprofit organizations differ substantially in the breadth of their value strategies. For example, the American Cancer Society attempts to address the full spectrum of the disease and invests in research, information, advocacy, and cancer control activities that cover this spectrum. In contrast, hundreds of other nonprofits with cancer in their name address niches associated with particular cancer sites, e.g., breast cancer, and promote a value proposition that emphasizes the merits of such focus.

Public sector organizations' value strategies tend to fall in two broad classes. One class of strategy attempts to provide the maximum value within the realities of available budgets. The other class attempts to minimize the budget required to provide a specified level of value.

[3] Of course, "profit margins" are not relevant in nonprofit and public sector enterprises. However, this distinction is not crucial if "profit," for all types of enterprises, is defined in terms of discretionary resources. It is also of note that discretionary resources in nonprofit and public enterprises are typically invested to enhance benefits or decrease costs since such resources cannot be used to pay dividends.

This oversimplification becomes much more complicated once one considers what is included in the definition of value. The Department of Defense, for instance, provides the means to defend U.S. interests. It also, however, directly provides jobs and contributes to economic developments, and indirectly provides R&D/technology outcomes that have repeatedly been found to benefit the overall economy.

3.2. R&D/Technology Organizations

The dimensions of quality, productivity, and innovation also apply to R&D/technology organizations themselves. Quality relates to readiness for technology transition in terms of technology maturity and reliability, availability of test results and documentation, etc. Productivity concerns the efficiency of resource utilization relative to creating R&D outcomes in timely manners. Innovation, as shown in Figure 1, ranges from incremental to disruptive technologies, which relates to levels of risk. Risks tend to increase costs—to assure acceptable levels of success—but high productivity can mitigate against such consequences.

In general, an R&D organization's value strategy relative to quality, productivity, and innovation should dovetail with the overall enterprise's value strategy. This is particularly true for innovation. Productivity is more likely to be inherently aligned because of the extent of cost sensitivity in the enterprise's culture, policies, and procedures. There may be less alignment in quality—for example, high quality technology may be needed to produce undifferentiated product quality at very low costs.

A strategy distinction of particular note for R&D organizations—especially in the public sector—is smart buyer vs. niche dominance. It is often argued that a primary purpose of R&D is to enhance staff abilities to make smart decisions concerning technologies acquired externally. In the public sector where all products are eventually acquired externally this argument is common.

This role is important in both the public and private sectors. However, sole focus on this role tends to result in less-than-stellar R&D organizations staffed by people who are content to be primarily observers rather than contributors to leading-edge aspects of science and technology. This tendency can be counterbalanced by also pursuing niche dominance in areas of high importance to the overall enterprise.

The niche dominance strategy tends to create an ethos of superior innovation and, when managed well, can also promote strong quality and productivity. When combined with the smart buyer strategy, niche dominance can also create smarter buyers. World class organizations are much more likely to be able to attract and acquire world class science and technology.

The remainder of this section explores the dimensions of quality, productivity, and innovation in some detail. This provides the basis for subsequent discussions of formulating and implementing value strategies. Also considered are the ways in which the constructs discussed in this article differ in for-profit, nonprofit, and public sector enterprises.

3.3. Quality

The concept of quality has attracted corporate interest and investment for many years, perhaps beginning with slogans such as "Zero Defects" in the 1960s and 1970s and maturing with Total Quality Management in the 1980s [Deming, 1986]. Initially, the emphasis was on product quality and eliminating defects, increasing reliability, and improving fit and finish. More recently, emphasis has grown to include services in terms of responsiveness and overall customer satisfaction.

The notion of quality in R&D organizations is fairly recent. Boff [2000], drawing upon both the broad quality literature and specific approaches to quality in the military [U.S. Air Force, 1996], discusses quality metrics for R&D in terms of outcomes/customer satisfaction (e.g., percent ratings of excellent), process (e.g., number of patents or publications), and system-related measures (e.g., percent workforce hours performing R&D).

Boff and his colleagues conclude that the metrics most applicable to R&D laboratories in general, and the Air Force Research Laboratory in particular, include:

- Process indicators that are internally assessable, e.g., number of patents and patent applications, number of technical publications and presentations, number of requests from operating units for technical assistance.
- Performance measures that are internally assessable, e.g., number of technologies and practices transitioned to operating units, percent on-time delivery, and percent R&D funds leveraged from external sources.
- Process indicators that are externally assessable by peer review or external audit, e.g., extent of critical mass of people, facilities and budgets, number of revolutionary capabilities produced, number of key people attracted from outside.
- Leverage and collaboration that are both internally and externally assessable, e.g., number of external partnerships and joint ventures created, number of joint efforts across organizational

units, percent of projects involving external peers.
- An overall customer satisfaction index that is externally assessable by survey or possibly interviews, keeping in mind the aforementioned distinction between next users and end users.

It is important to note that the nature of the above metrics reflects quality for both projects and overall characteristics of the organization. Further, some of these metrics relate more closely to productivity (e.g., number of technologies transitioned) and innovation (e.g., number of revolutionary capabilities produced). Nevertheless, the types of metrics listed above are definitely the types needed within the framework advanced in this article. These metrics and others are discussed when "balanced scorecards" for R&D organizations are later discussed.

3.4. Productivity

Productivity is classically defined as output divided by input—the higher this ratio, the more productive the organization. This simple definition immediately raises the questions of what is meant by output and input. Pursuit of these questions quickly exposes the complexity of productivity.

Outputs. What is the output of an R&D organization? A recently completed series of studies involved identifying and reviewing 25 high-quality empirical studies of management practices [Rouse, Thomas, and Boff, 1998]. Table I summarizes the dependent measures employed in these studies to assess the impact of various independent variables. This summary indicates 27 types of metrics, representing 156 instances of measurement. Note that the top one third of these metrics reflect two thirds of the measurement instances—a skew that is usually found in compilations of this sort.

This top third (i.e., 9) emphasize output in terms of delivering the promised technology and succeeding in the marketplace. Only two metrics, representing just one eighth of the measurement instances, focus on process measures—in this case, cross-functional cooperation and innovative behaviors. Thus, there is a strong emphasis on "bottom line" assessments of the impact of R&D investments. It is important to note that this is probably due to the nature of the organizations studied, i.e., companies manufacturing and selling products with goals of revenue and profits.

Actual measurement practices in technology-based industries range from global measures such as profit per employee [Cohan, 1997] to process measures such as papers published and patents granted. Consider IBM's practices [Gwynne, 1998]: "Obviously you can't measure a research organization the same way you can a product or sales unit." (Chairman and CEO Louis) Gerstner explains: "But IBM research has developed a highly sophisticated system that recognizes and respects the need for balance between short-term returns and long-term investments that may—or may not—pay off in the future. Very importantly, we also benchmark IBM research against the best in the world—other industrial research organizations and universities. We measure our ability to attract and retain world-class researchers, our patent leadership position, our visibility in journals, and our presentations at high-level conferences."

While it seems reasonable to assert that the output of an R&D organization is products that tangibly support the overall enterprise's outputs, this conclusion presents difficulties. Many products of R&D are never employed because of changing markets, budget constraints, and other factors outside the control of R&D organizations. For military R&D, technologies may be transitioned to weapon systems, but there systems may never be used. For these reasons, it makes more sense to measure R&D outputs in terms of the number of viable technology options created. While not all options will be exercised, there is considerable value in having options which can be assessed using option pricing models [Rouse, 2000a; Rouse et al., 2000].

Not all R&D outputs are technology options, ready to be exercised if later conditions are right. R&D, especially long-term research, often produces knowledge rather than technologies. Rouse [1998a] discusses the notion of knowledge productivity. He suggests that at least one measure of an R&D organization's outputs should be "knowledge solutions" that include:

- Valid fundamental knowledge, e.g., number of archival journal articles.
- Translated into usable forms, e.g., number of design methods.
- Provided in useful manners, e.g., number of short courses and design aids.

Overall knowledge productivity is likely to be the product, rather than the sum, of these three measures.

Inputs. Traditional economic indices of productivity have focused on output per labor input. Such inputs may be characterized in labor hours or labor costs which often include costs of employee benefits and other costs directly linked to labor hours. Thus, one might characterize R&D productivity, in part, in terms of number of patents or publications per labor hour or dollar.

A limitation of only viewing labor as input is that it ignores other inputs (resources) required to produce output. The inputs to an R&D organization include its

Table I. Frequency of Use of R&D Outputs Metrics

No.	Metric	Frequency	Percentage	Cumulative
1	probability of success	31	20%	20%
2	new product market performance	21	13%	33%
3	project performance	10	6%	40%
4	probability of technical success	8	5%	45%
5	cross-functional cooperation	7	4%	49%
6	innovative behavior	7	4%	54%
7	probability of commercial success	7	4%	58%
8	business innovation	6	4%	62%
9	rate of inventive output	6	4%	66%
10	allocation of funds	5	3%	69%
11	centralization	5	3%	72%
12	development time	5	3%	76%
13	R&D productivity	4	3%	78%
14	job involvement/satisfaction/time commitment	3	2%	80%
15	likely continued existence of the market	3	2%	82%
16	number of innovations	3	2%	84%
17	number of patents	3	2%	86%
18	R&D activity	3	2%	88%
19	R&D project quality	3	2%	90%
20	technical quality	3	2%	92%
21	access and utilization of information	2	1%	93%
22	external relations and visibility	2	1%	94%
23	delivery lead times	2	1%	96%
24	new product defects	2	1%	97%
25	number of articles	2	1%	98%
26	technical success	2	1%	99%
27	levels of formalization	1	1%	100%

overall budget (for R&D and overhead), a portion of facilities operations and maintenance budgets, capital costs of buildings and equipment, and a portion of the real estate value of the land on which buildings are located. This kind of tally would clearly result with estimates of very substantial inputs.

This approach to assessing inputs makes it quite possible to have very productive researchers and a very unproductive organization. If major portions of budgets are not associated with output-producing activities, overall productivity decreases despite the high productivity of the output-producing entities. This phenomenon can be masked by an organization's cost attribution practices. For example, if the costs not associated with producing outputs are attributed to overhead costs of individual researchers, it will appear that individuals rather than the organization have productivity problems.

The difficulties of attributing costs are much more substantial for public sector organizations. For instance, facilities often serve multiple constituencies and cannot be closed or realigned without overcoming substantial political pressures. Thus, efforts to create lean R&D enterprises may be thwarted. As a result, the input side of productivity is likely to be inflated compared to what it might be in the private sector. This makes cross-sector comparisons of productivity quite difficult.

To illustrate this difficulty, consider how federal R&D budgets approved by the President flow through to researchers in industry. Roughly one third of the budgeted monies actually make it to the laboratory personnel managing the R&D contracts with industry. Similarly, roughly one third of the monies sent to industry flow through to pay the researchers' salaries—the R&D equivalent of "touch labor." Thus, the overall multiplier from research salaries to President's budget is roughly ten.

Given these assumptions, if researcher productivity increases by a phenomenal 50%, overall productivity as seen by Congress and the public increases by a modest 5%. Industry long ago realized the eventual limited returns of focusing solely on improving the productivity of touch labor and the need to address overhead costs. Activity-based cost accounting [Cooper and Kaplan, 1988] is a key means to success in this area. However, the applicability and acceptability of such methods within the public sector are unclear.

Summary. At this point, we have discussed R&D in terms of quality and quantity (productivity). Superior quality and excellent productivity are clearly desirable characteristics of R&D organizations. However, these characteristics are seldom sufficient for assuring sustainable competitive advantages for the overall enterprise. Beyond doing R&D right, one has to do the right R&D.

3.5. Innovation

Innovation has in recent years become an increasingly popular topic, in part because of large enterprises' perceptions that it is quite difficult to do new things both quickly and well [Christensen, 1997; Rouse, 2000a]. As noted by *The Economist* [1999, p. 61], "Unlike cutting jobs or making an acquisition, innovation does not happen just because the chief executive wills it."

Definitions. The many debates and discussions of this topic often stumble over definitions of innovation. The following alternatives capture how innovation is viewed in this article:

- "Innovation is the introduction of change via something new. Many innovations take advantage of one or more inventions—new devices or processes—but these inventions are not the innovations. The vast majority of inventions and good ideas in general do not result in change. They do not become part of products or services in people's hands, being used to be productive, make life easier or safer, or bring enjoyment." [Rouse, 1992, p. 1].
- "One must be careful to distinguish innovation from discovery. You can only manage discovery by setting direction and hiring people to work in that direction with the hope of great discoveries. Innovation, the process of taking a discovery or idea to the market, is something that must be managed carefully, and we work hard to do this." [Brinkman, 2000, p. 18G].
- "My definition of innovation is invention, or doing things differently, that leads to business success. By this definition, without a business success, there is no innovation." [Heilmeier, 2000, p. 26].
- "Research is the transformation of money into knowledge; innovation is the transformation of knowledge into money" (informally attributed to Bayer).

The distinction between innovation and invention or discovery is very important. Many enterprises consider themselves to be innovative, despite flat sales and sagging profits. In such situations, it is often the case that they are reasonably inventive, but not as innovative as they perceive themselves to be. Xerox's failure to translate its personal computer inventions to market innovations provides a good example [Smith and Alexander, 1988].

Presented with this observation, they often say, "But, our employees are full of good ideas and have created lots of neat things." This assertion is almost always correct. Their perceptions that their employees are inventive is usually well founded. However, at the same time, this plethora of inventions has seldom resulted in change in these companies' markets or, in general, for these organizations' constituencies. Value provided to the marketplace or for constituencies has not increased. Their inventions did not result in innovations.

Difficulties. The fact is that innovation is difficult. There are a variety of underlying sources of these difficulties [Christensen, 1997; Hamel, 2000; Rouse, 2000a]:

- Being trapped by the paradigm that got you where you are, often requiring continued investment in paradigms that knowingly cannot be sustained.
- Requiring gross margins—dictated by existing cost structures—that cannot be sustained by a nascent innovation.
- Requiring opportunity size—due to the current denominator in the percent growth calculation—that cannot be initially achieved by new ideas.
- Employing formal decision processes that undermine new ideas by requiring inherently unavailable information and strongly discounting uncertain returns.
- Requiring alignment of all key stakeholders which, at the very least, lengthens the time to decisions and also demotivates champions.
- Obeying rules that do not exist such as regulatory dictates or company policies and procedures interpreted much too strictly.
- Needing to work outside and/or around process-bound organizations and bureaucracies in order to accomplish anything outside the reigning paradigms [Rouse and Boff, 1994].

Beyond such difficulties, there is the simple truth that the odds of innovation are quite low. Stevens and Burley [1997] reviewed a wide range of empirical assessments of chances of commercial success and concluded that 3000 ideas are needed for one success. Nichols [1994] suggests 10,000:1 is the right ratio for the drug industry.

Innovation Funnel. This phenomenon leads to the notion of an innovation funnel such as shown in Figure 2. Managing the flow of projects and outcomes through this funnel is a critical management responsibility, with the ability to deliver value depending on how well this management task is done. A typical goal is to invest in 200–300 entry-level projects at the left of the funnel, prune steadily throughout the funnel, and eventually produce 1–2 commercially/operationally successful innovations from the right of the funnel.

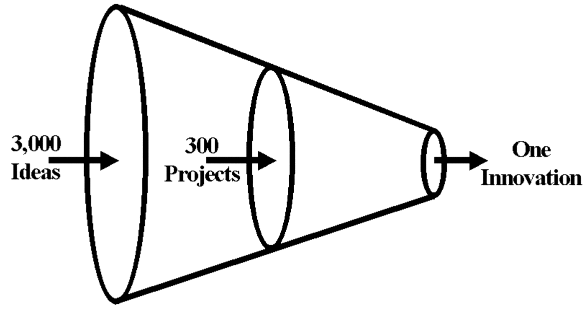

Figure 2. The innovation funnel.

It is important to note that the nature of the projects in the funnel tend to differ along the innovation axis in Figure 1. Incremental innovations tend to be driven by the marketplace. Investments in such projects tend to be smaller, as are the risks. Results are also small to moderate. In contrast, disruptive innovation tends to be technology driven. Larger investments are needed, involving substantial risks. The motivation for such investments is the likelihood of much greater returns.

The nature of the funnel in Figure 2 presents difficulties in many organizations. At an extreme, key stakeholders may respond to this rather low yield by saying, "If only 1 in 300 projects will eventually be successful, let's just invest in the successful one." However, R&D/technology simply does not and cannot work this way. It is inherently risky. Abilities to understand and manage these risks can yield high returns in the marketplace or on the battlefield. This argument, unfortunately, may not be compelling to public constituencies hoping to minimize "waste" and viewing as waste all R&D that does not yield outcomes that transition to use.

3.6. Measurement

Considering the three dimensions of value strategies in Figure 1, plus the elaboration of these dimensions just discussed, it is natural to ask how one assesses one's current strategies, predicts the impacts of new strategies, monitors the evolution from "as is" to "to be," and manages risks via such measurements. These types of questions merit treatment substantially beyond the scope of this article. Jensen and Sage provide a systematic approach to such measurement questions [Sage and Jensen, 1999; Jensen and Sage, 2000].

Rucci, Kirn, and Quinn [1998] provide a good illustration of how measurement can play a central role in formulating value strategies. They report on an effort focused on improving the value/profit chain at Sears. Their underlying premise is that a compelling place to work is more likely to be a compelling place to shop which will, in turn, be a compelling place to invest. This premise offers the promise of being able to increase market value by improving processes within stores.

They present a statistical model that relates employee attitude to customer impressions to revenue growth. This model was used to design a program to improve employee satisfaction and attitudes. Measured results indicate a 4% increase in employee satisfaction, 4% increase in customer satisfaction, $200M increase in revenue, and $0.25B increase in market value. Thus, the logic of the model appears to reflect the reality of actual results.

This example shows how a retail company addressed the multidimensional nature of value in their marketplace, in this case with emphasis on quality and productivity of employees and satisfaction of customers. The same line of reasoning can be applied in other domains such as R&D. Value chains in this domain include research projects, development projects, initial product launches, derivative product launches, and ongoing product support [Rouse et al., 2000]. Such value chains are admittedly more subtle and involve extended time horizons. Nevertheless, the measurement issues are, in principle at least, quite similar.

One particular measurement difficulty deserves special mention. The multidimensional nature of value advocated in this article tends to promote multidimensional organizational changes involving several minor and possibly major changes associated with each of the three dimensions. This can make it very difficult to measure the impact of changes, especially any subset of the changes. This process is further complicated by the fact that enterprises are usually reluctant to invest in measurement efforts associated with low-volume processes like R&D, due to the simple fact that the payoffs from continual improvements of processes are highly dependent on the volumes processed.

Nevertheless, there are methods and tools that can help plan, implement, and monitor measurements of the dimensions of value. Multistage decision processes and balanced scorecards are two particularly noteworthy methods and tools. Later discussion focuses on the application of these constructs to value strategy implementation and evaluation. While ongoing use of the overall value framework presented here should eventually lead to case study data supporting the merits—or demerits—of this framework, such data are only slowly beginning to emerge.

4. FORMULATING VALUE STRATEGIES

Formulation of a value strategy can be pursued via the following steps:

- Choosing where to provide value, i.e., what "business" to be in.
- Deciding how to provide value—starting with the three dimensions in Figure 1.
- Developing an enterprise design that enables providing value in the chosen way(s).
- Benchmarking where you stand, both in terms of the three dimensions in Figure 1 and relative to your enterprise design.
- Determining how to close the gaps between "as is" and "to be."
- Implementing resulting plans, monitoring progress, and making mid-course corrections, often due to recognition that assumptions need to change

The process can be the same for all types of organizations, although the upstream steps for R&D/technology organizations (and similar organizations) typically involve dovetailing with the longer-term intentions of business units, operating units, or other constituencies rather than the enterprise's "marketplace" directly.

Pursuit of the above steps for an R&D organization also depends on the enterprise's overall view of the role of R&D. If, for example, the role of R&D is to focus on incremental quality and productivity improvements of existing product lines, it is unlikely that an R&D organization can succeed by emphasizing innovation. In contrast, if the enterprise's focus is on a steady stream of product and service innovations, an R&D organization's success is likely to depend on also emphasizing this dimension of value.

A good illustration of this difference is provided by the defense establishment. For the past decade, there has been strong emphasis on living within quite constrained budgets despite a wide range of military operations throughout the world involving adversaries with markedly inferior technology positions. Consequently, desires for incremental quality and productivity improvements have displaced a long tradition of investing in technological innovation. Put simply, the overall defense enterprise has changed its value strategy, which has required defense R&D organizations to revisit their strategies.

4.1. Inferring Roles of R&D/Technology

Not infrequently, R&D organizations must formulate value strategies in the absence of an overall enterprise value strategy [Rouse, 1998b]. In such situations, an R&D organization may have to infer the overall enterprise's answers to the following questions:

- What "business" are you in?
- What "business" do you aspire to be in?

- What is the nature of the gaps between "as is" and "might be"?
- How can these gaps be filled?

The second question is often the most difficult. A primary source of this difficulty is the often overwhelming—but usually unspoken—desire to succeed in the future in exactly the same ways that success was achieved in the past [Martin, 1993; Rouse, 1996, 1998b]. However, as Slywotsky ably illustrates, it is rare that success can be sustained without changing value propositions [Slywotsky, 1996; Slywotsky and Morrison, 1997].

Current trends in information technology are pervasively and rapidly changing most enterprises' value propositions. Emerging trends in biotechnology will increasingly affect the value propositions of enterprises in health-related and food markets. As the military increasingly becomes driven by small-scale expeditionary operations and threats from unconventional adversaries, its value proposition is shifting from providing the means for massive military operations to fast and flexible responses to a wide range of more focused missions. This is further complicated by the fact that the most effective military responses may involve new weapons (e.g., information) rather than traditional weapons (e.g., airplanes). R&D organizations associated with enterprises affected by these trends—which includes nearly all enterprises—should provide their enterprises with options for succeeding in the future(s) that these trends portend.

4.2. R&D/Technology Options

Options-oriented thinking can help R&D organizations to address these needs [Amram and Kulatilaka, 1999; Rouse, 2000a; Rouse et al., 2000]. A primary purpose of an R&D organization is to provide the overall enterprise the science and technology options it needs for the future. Many of these options will not be exercised, but the set of options collectively provides the enterprise the essential flexibility to adapt its value proposition as needed. With this perspective, an R&D organization can focus on the likely range of options needed by the enterprise, whether or not all of these needs have been explicitly articulated in the enterprise's long-term intentions.

Thus, the value strategy of an R&D organization can be driven by both the explicit value strategy of the overall enterprise and the often unstated needs that can be inferred by study of current and emerging trends that are affecting or likely to affect the enterprise. The abilities of an R&D organization to create a portfolio of technology options in this way is, admittedly, heavily influenced by the extent of its discretion to address unstated needs. If business or operational units limit R&D investments to explicitly stated needs, it is much more likely that long-term options will receive little attention. For this reason, the level of discretion of top management of R&D organizations is a critical issue.

4.3. Designing the Enterprise

The next question concerns designing the R&D/technology enterprise to deliver value to the enterprise and other constituencies. In general, developing an enterprise design involves addressing the following questions:

- How will you compete?
- Why will this work?
- What are your value streams?
- How do your processes support these value streams?
- What organizational design is implied by this enterprise design?

From the perspective of an R&D organization, these questions concern how to compete for scarce resources—which might otherwise be used for nearer-term investment—and understanding how value flows from R&D to the overall enterprise. This leads to assuring that organizational processes support and contribute to these value streams, and designing the organization accordingly. For example, the R&D organization might be organized by science and engineering disciplines, cross-cutting technology trusts, or product lines supported—or perhaps some hybrid.

Benchmarking is central to formulating value strategies that are realistically implementable. The current position of the organization ("as is") compared to its aspirations ("to be") defines the gaps that should be filled in order to implement the value strategy being entertained. Key questions include:

- Where do you stand?
- What are the gaps between you and "best in class"?
- How can these gaps be closed?
- How can you become the best in class?
- What resources will be required?

There are a range of methods and tools available to support addressing such questions, with emphases ranging from external forces [Rouse, 1996], to internal processes [Madni, 2000], to change management [Majchrzak and Gasser, 2000].

4.4. Change Strategies

A central element of a value strategy concerns how the organization will accomplish the changes dictated by

Table II. Steps in Developing Change Strategies

Step	Description
1	Create and communicate a compelling story for why change is needed.
2	Formulate a vision and associated goals and objectives that define the desired state.
3	Establish the organizational baseline state relative to the goals and objectives.
4	Determine what strengths can and should be drawn upon to close the gap between desired and current states.
5	Identify where discretion is acceptable and perhaps needed relative to how the gap is closed.
6	Define a series of relatively small changes that, in combination, accomplish the large change sought – look for "small wins."
7	Identify organizational impedances to accomplishing this series of changes.
8	Determine which impedances can be overcome and how this can be accomplished.
9	Communicate how steps will be implemented well in advance of actual implementation.
10	Measure and communicate progress and adapt the change strategy along the way.

adopting a new value strategy [Rouse, 2000a]. The steps shown in Table II, drawn from numerous sources, have been found to provide a useful way for addressing such changes. Note that while this process is depicted as a step-by-step linear process, pursuit of this process usually involves much parallel activity and significant iteration.

This process can be applied to each dimension of value—quality, productivity, and innovation—and possibly to each metric within each dimension. It is essential that top management's commitment to this process be articulated and frequently reinforced. This commitment is a key success factor with any change processes [Rouse, 2000a].

There is an almost overwhelming tendency of organizations to succumb to the delusion that they can pursue new value strategies with old enterprise designs and organizational structures and systems [Rouse, 1998b]. However, the "old" enterprise and organization were designed (or evolved) for the purpose of achieving old goals. It is very unlikely that the status quo is the best way to achieve new goals, especially if the new goals are significantly different than the old goals.

5. IMPLEMENTING VALUE STRATEGIES

Perhaps the most common failure of strategic plans is poor implementation or lack of implementation [Rouse, 1998b]. A key aspect of avoiding this fate concerns assuring support and commitment of key stakeholders. For external stakeholders (e.g., customers), this often involves changing perceptions of the roles and value provided by the enterprise. Gaining commitment of internal stakeholders typically involves changing incentive and reward systems while also consciously evolving the enterprise's culture, in part by judiciously adding new personnel.

As noted in the last section, these changes are likely to require a carefully planned external and internal marketing program, possibly including some elements of training for internal stakeholders. The credibility of the "messages" associated with this program are likely to depend on creating some "easy wins" early to assure stakeholders that both the value strategy is more than just words and that successful pursuit of the strategy is feasible.

5.1. Managing Change

Changing external and internal perceptions is almost always difficult and especially difficult in large enterprises with deeply ingrained cultures. As just indicated, it can be useful to develop an explicit change management strategy for accomplishing such transformations. Beer and Nohria [2000] outline two broad classes of strategies, or perhaps philosophies, with which to pursue the steps outlined earlier.

One class is oriented around economic value. With strategies in this class, one manages change top down, emphasizing organizational structure and systems.

Change programs are planned, established, and managed. Business process reengineering fits squarely in this class. One might term this strategy the "command and control" approach to change.

The other class of strategies emphasizes organizational capability. With these strategies, bottom-up participation is encouraged. Building of corporate culture is the overarching goal. Experimentation and evolution are central themes. Learning organizations and communities of practice are good examples of concepts that fit in this class.

Balancing these two perspectives appears to be the best practice. Purely top down strategies often encounter resistance—or, more likely, apathy—at lower levels, especially in R&D organizations where individual accomplishment is often inherently a strong element of the culture. Totally bottom-up strategies, on the other hand, can lead to fragmentation and inefficiency, particularly in R&D organizations where tangents are often viewed as opportunities.

The right balance is highly situation and culture dependent and can be quite difficult to identify and achieve. Several tactics that can help include:

- Organizational development initiatives can be used to help people to understand new value strategies, as well as gain the knowledge and skills required to contribute to implementing these strategies [Boff, 2000]:
  —Proactive communication of the new value strategy,
  —Clarification of specific individual responsibilities,
  —Education and training for new knowledge and skills needed,
  —Training the trainers to "flow down" the knowledge and skills.
- Carefully selected new personnel can be used to "infect" the cadre of existing personnel—in R&D organizations, this usually depends on the new personnel being highly respected and good communicators.
- New organizational elements can be acquired with cultures and practices that are aligned with new value strategies—in R&D organizations, this may involve acquiring whole research teams or small R&D organizations.
- Units can be spun off and/or functions outsourced to eliminate tensions between old and new value strategies—units that embody either the old or new strategies can be launched depending on which is more feasible.

The key in employing these tactics is to clearly understand how the new value strategy is best supported and what elements of the old value strategy should be retained. Further, it is important to understand how the new strategy and elements of the old strategy are to be integrated.

5.2. Multistage Decision Processes

The value strategy for an R&D organization should be reflected in the portfolio of projects undertaken. Best practices for managing R&D project portfolios—as well as new product project portfolios—include utilization of multistage decision processes [Cooper, 1998]. Typical stages for new product development include ideation, preliminary investigation, detailed investigation, development, testing and validation, production and launch, and market innovation. For R&D/technology projects, a more appropriate designation for these stages might be the following:

- Ideation
- Concept paper
- Initial project
- Exploratory development program
- Advanced development program
- Technology transition
- Innovation

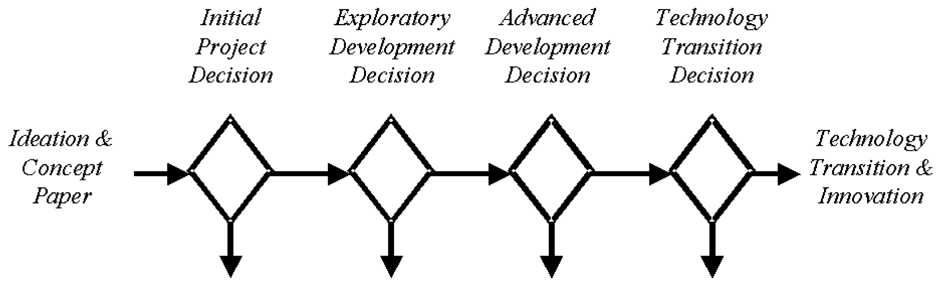

Figure 3. Multistage decision process.

Critical decisions between these stages are depicted in Figure 3. Projects exit this process all along the way, resulting in many more projects in earlier stages than at later stages—hence, the aforementioned funnel in Figure 2. It is important to emphasize the fact that exiting projects are not failures in that, at the very least, they provide knowledge about what does not work and what cannot be cost effective. Unfortunately, most organizations are quite poor at capturing such knowledge.

Possible criteria for transitions between the stages in are shown in Table III. Note how the attributes of interest remain unchanged across stages, but the criteria become more stringent as projects make their way through the innovation funnel and require greater commitments of resources. Criteria may also change with stages due to varying stakeholders across stages, i.e., the next user usually differs from the end user for all but the last stage.

There is a natural tendency to assume that a central premise underlying such multistage processes is that projects can and will smoothly move through the stages. However, some projects in exploratory development, for example, may stay at that stage for an extended period of time without explicit intentions to transition. Further, not all ideas and projects enter the funnel from the left. More mature ideas and projects, e.g., originated by partners, may enter at exploratory or advanced development. Thus, the metaphor of a funnel should be loosely interpreted.

It is important to realize that the nature of what transitions between stages may vary, ranging from people to information to prototypes to requirements—but rarely in the form of off-the-shelf technology. This can be thought of in terms of data vs. information vs. knowledge, transitioned either in formal documents or informally in people's heads. In fact, it often appears that the speed with which projects move through the funnel is highly related to the flexibility with which people move throughout the enterprise.

5.3. Organizational Implications

Multistage decision processes do not change everything in an organization, but they do affect a few things quite significantly:

- Organizing by "product" lines (e.g., technology thrusts) tends to replace organizing by disciplines.
- Integrated product teams, or equivalent, provide means for disciplinary involvement throughout the multistage process.
- While budgeted organizations and reimbursable organizations are both common, hybrid approaches to R&D investment are becoming popular.

A multistage orientation also has implications for recruiting, selecting, developing, and rewarding R&D personnel:

- Expertise needs shift from purely disciplinary knowledge and skills to needs to also have staff oriented toward transitions of knowledge and technology to application.
- Emphasis shifts from people oriented toward individual accomplishment to people more willing and able to work on teams and share information in order to accomplish organizational goals.
- Recruiting, selection, and retention processes are changed to assure the needed mix of personnel, with increased emphasis on commitment to outcomes and working on teams.
- Incentives and rewards also change considerably with raises, promotions, bonuses, and opportunities tied to results, and senior executives held responsible for achieving value goals.

Collectively, these structural and staffing implications may represent substantial changes for many R&D organizations. Nevertheless, such changes are likely to be central to successful implementation of value strategies.

5.4. Balanced Scorecards

Beyond managing the portfolio of R&D projects, one needs to mange the overall R&D enterprise. The notion of a "balanced scorecard" [Kaplan and Norton, 1996] can help in this process. Creation of a balanced scorecard involves defining 2-4 critical measures in each of four strategic areas:

- Customer
- Financial
- Internal Business Processes
- Learning & Growth

For each measure in each area, the balanced scorecard specifies objectives, measures, targets, and initiatives.

Table IV indicates a possible balanced scorecard for an R&D/technology organization, drawing upon the earlier discussions of quality, productivity, and innovation. Rather than attempting to develop a single index of value, this balanced scorecard recognizes the multiattribute nature of value and the need to define attribute-specific targets which, in turn, drive the initiatives undertaken.

Table III. Criteria for Decisions at Each Stage of Process

	Decision				
Decision Criteria	Idea → Concept Paper	Concept Paper → Initial Project	Initial Project → Exploratory Development	Exploratory Development → Advanced Development	Advanced Development → Technology Transition
Strategic Fit	NA	Possible	Definite	Priority	Programmed
Payoff	NA	Imaginable	Articulated	Projected	Demonstrated
Schedule	NA	One-year deliverables	Multi-year sequence of deliverables	Multi-year sequence of demonstrations	Technology transition plan
Resources	No budget	Discretionary budget available	Budget scoped appropriately	Costs/benefits projected	Costs/benefits assessed
Technical Risk	NA	NA	Anticipated	Managed	Minimized
Application Risk	NA	NA	NA	Anticipated	Managed
Personnel	Interest & commitment	Commitment & credibility	Commitment & credibility	Credibility & availability	Credibility & availability
Competencies	Desirable & obtainable	Desirable & developing	Available internally & externally	Available internally & externally	Demonstrated & available

Table IV. Balanced Scorecard for Value Strategies

Customer				Financial			
Objectives	Measures	Targets	Initiatives	Objectives	Measures	Targets	Initiatives
Customer Satisfaction				Internal Budget			
Technology Transferred				External Resources			
Operational Cost Savings				Collaboration/ Joint Ventures/ Partnerships			
Internal Business Processes				**Learning & Growth**			
Objectives	Measures	Targets	Initiatives	Objectives	Measures	Targets	Initiatives
Budget/Service Variances				Publications/ Patents			
Goal Variances				Recognition of People & Technologies			
Facilities/ Equipment Quality				Training Accomplished			

In practice, key stakeholders debate, discuss, and agree upon the objectives, measures, and targets included in the balanced scorecard. Initiatives then become the responsibility of individuals, managers, and staff personnel. Progress is typically reviewed quarterly. Results are reviewed annually, which prompts reconsideration of objectives, measures, and targets. During this annual review, the organization collectively takes responsibility for the whole scorecard. The tenor of the discussion then focuses on where "we" succeeded or failed, rather than where those responsible for individual initiatives succeeded or failed.

5.5. Adapting Value Strategies

The nature of change strategies, multistage decision processes, organizational design, balanced scorecards, etc. usually must be tailored to the context within which value is to be provided. This includes the nature of products and services, as well as the type of organization.

Balachandra and Friar [1997] suggest that context can be captured with three dimensions:

- Nature of innovation—incremental vs. radical
- Nature of market—existing vs. new
- Nature of technology—low vs. high

Incremental innovation in existing markets via low technology is more predictable and manageable than radical (or disruptive) innovation in new markets involving high technology. The most relevant and useful metrics are much clearer. Internal and external benchmarks are usually more readily available.

At the other extreme of these dimensions—radical, new, and high—the most appropriate metrics may be very unclear, especially those related to market needs and preferences. Benchmarks, particularly those related to timing may be more guesses than estimates. Consequently, decision criteria and scorecards may have to be used much more qualitatively.

Another difference between these two extremes is the relative weighting of stakeholders' desires. In the former case, stated needs and preferences of current customers and users are paramount, e.g., for military R&D, the warfighter knows what he or she wants. In the latter case, the desires of current customers and users are much less useful and, in some situations, can be quite distracting.

Criteria, scorecards, etc. must also be adapted to differences among for-profit, nonprofit, and public enterprises. A central difference concerns the nature of constituencies. Private sector enterprises usually have quite well-defined stakeholders, with a relatively well-understood set of perceptions, values, and concerns. Public sector organizations, in contrast, often have a wide range of stakeholders. Large, volunteer-oriented nonprofit enterprises can also have a wide variety. To the extent that different stakeholders have competing interests, all of which cannot be served, defining and delivering value becomes multidimensional and complicated.

Another difference relates to the nature of goals, which are often as varied as the range of stakeholders. To the extent that unifying goals cannot be agreed upon, compromises across possibly conflicting goals become necessary and require careful consideration of higher-order effects. Provision of value to one interest group at the expense of value to another interest group can create difficulties in other arenas.

Such differences impact the nature of decision making processes. To the extent that explicit decision-making processes will be subject to significant criticism and manipulation, final decisions may rely more on negotiation than optimization. Specifically, key stakeholder groups may require shares of resources regardless of the merits of how they will invest these resources.

All of the above have important implications for multistage decision making processes. In particular, key decision criteria may be unrelated to the value provided by the organization and more influenced by organizational considerations. For example, criteria such as "sellability" and "defendability" of investments can become central to downstream decisions.

These observations are not meant to discourage application of the ideas in this article to nonprofit and public sector enterprises. Instead, they are intended to sensitize managers in such organizations to the possible difficulties in applying business best practices in nonbusiness organizations. Inherently conflicting interests and decision-makers who have more influence than control require skillful and insightful applications of these best practices.

6. CONCLUSIONS

This article has focused on formulating and implementing value strategies in environments where the multistakeholder, multiattribute nature of value precludes single-minded emphasis on shareholder value. Formulation of value strategies has been characterized in terms of defining aspirations along three dimensions—quality, productivity, and innovation. These dimensions were discussed for enterprises in general, and R&D/technology organizations in particular, the latter being the focus of this article.

Strategy formulation was considered in terms of sets of questions related to where to provide value, how to provide value, what enterprise design to adopt, benchmarking "as is" versus "to be" gaps, and determining necessary actions plans for closing gaps. Strategy implementation was discussed relative to strategies for change, multistage decision processes, organizational implications, balanced scorecards, and adapting value strategies to different types of enterprises.

Much of the discussion in this article applies to enterprises in general. However, there are several considerations particular to R&D/technology organizations. The returns from investments in R&D are inherently long-term and highly uncertain. In light of such uncertainties—in nature, as well as time and magnitude—it is useful to characterize the purpose of R&D as providing technology options which the overall enterprise may or may not adopt in the future. This leads to value for R&D organizations being defined in terms of the quality, productivity, and innovation dimensions of options provided to the overall enterprise.

It was noted that considerable attention should be paid to the implementation strategy associated with pursuit of a new value strategy. Significant organizational changes are often needed, and it should not be expected that such changes will happen without concerted attention. An explicit change process is usually needed and top management must commit to this process. This includes commitment of resources for the organizational development required to assure successful change.

As indicated earlier, to a great extent the framework advocated in this article borrows from and subsumes many contemporary management constructs, for example, Total Quality Management (quality), Business Process Reengineering (productivity), and Knowledge Management (innovation). Combining contemporary thinking about the role of R&D/technology in enterprise strategy with this wide variety of popular management nostrums leads to an overall framework for formulating and implementing value strategies in R&D organizations.

The work upon which this article is based has led to a particularly important insight. Value is a very popular concept, as are quality, productivity, and innovation, not to mention various popular acronyms in these arenas (e.g., TQM, BPR, and KM). Tremendous progress can be made by simply assuring that all the stakeholders in developing and implementing a value strategy are discussing and debating the same things. From this perspective, an integrative framework—as opposed to an alternative framework—is exactly what is needed to move beyond all the competing points of view.

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