Strategic Planning for High-Tech Product Development

GEORGE SCOTT

ABSTRACT A three-questionnaire DELPHI management issues study of technology management problems identifies the top 24 technology management problems of advanced-technology product companies. These problems are ranked in order of importance. Strategic planning for technology products is found to be the dominant problem. A striking theme of the findings is the extent to which several of the twenty-four issues are related to this dominant problem. Arguably, not only is strategic planning the top technology management problem of product development in high-tech companies but it is also the cornerstone problem. Dealing effectively with this top problem will require attention to aspects of several others of the management problems.

This article first examines the area of strategic planning in advanced-technology product development. It then summarizes the DELPHI study’s findings and explores the central role among these findings of strategic planning for technology products. The next 10 problems in importance then are examined in the context of their relationship to the top issue of strategic planning for technology products.

Introduction

Few will argue with the premise that the development of new, advanced technology products—from advanced commercial aircraft, to computer software, to high-tech razors and blades—has a major impact on society and is a major factor in the success of many companies as well as a primary basis for their competitiveness. For a particular technology company, to continue to enhance its competitive position requires that the processes of advanced-technology product development and introduction continue to be improved.

Several activities influence the flow of a company’s advanced technology products. Two important types of activities are those associated with developing new technologies and products, and those involved with taking these products forward to the marketplace. These activities must be managed, which usually is referred to as ‘technology management’.

Technology management is concerned with the coordinated management of all high-tech product development activities and processes, including technology acquisition, the several dimensions of product development and the market launch of the product. These management activities are always present in technology companies in one form or another, but may not be of high quality, or may be separated into functional smokestacks of R&D management, management of engineering design, process design management, manufacturing management, ramp-up management, management of product introduction activities and technology product family management activities, or other similar areas. In many companies the same careful attention given to the development of the
technologies themselves is not given to the coordinated management of all aspects of high-technology product development, inclusive of manufacturing ramp-up, and marketing’s product introduction processes. Yet, to achieve commercial success all of these activities should be carefully managed as one end-to-end, cross-functionally integrated process. Scott suggests the ways in which activities are melded into this end-to-end integrated process.

The research of this article examined the question of ‘which technology management problems remain unresolved in many companies?’ The author conducted a DELPHI questionnaire study dealing with this concern about identifying unresolved technology management problems.

A major finding of this study is that the most important problem area of management of high-tech product development and commercialization is Strategic Planning for Technology Products. The study’s results also suggest that many of the other top problems identified are related to this strategic planning problem. Accordingly, the purposes of this article are to: (a) explore the discussion provided by the study’s expert participants about the Strategic Planning for Technology Products problem; and (b) relate others of the important problems identified by the study to this top problem. Preliminary to directly examining the study’s findings about the most important problem involving strategic planning, a brief review is given of developments of the recent decades with respect to strategic planning.

The Re-emergence of Strategic Planning

Rapidly advancing technology tends to increase a technology company’s complexity. As new technologies emerge, fragment and divide again and again, a greater number and diversity of products results, which increases the complexity of operations. The greater operations complexity requires that a company make more choices, such as determining which technologies should be pursued further and hence receive funding, which new markets should be entered with which of the many products, and when and how to exit which markets and terminate particular products in an orderly fashion, and so on. Unbridled complexity can cause chaos and can impact product quality.

Companies deal with complexity in a number of ways. These ways include simplifying operations, directly attacking the consequences of complexity (such as by implementing quality control programs), implementing operations and management control systems (especially, computer based control systems), exercising greater discipline (sometimes referred to as ‘out-executing the competition’), implementing new management systems and techniques that often are abetted by computer systems (e.g. just-in-time inventory management), and by planning.

Planning activities are commonly used by companies for establishing a context within which choices are made, such as for comparing alternatives and choosing a particular direction for business activities and for management control of activities. One type of planning, strategic planning, usually is viewed as an activity for which senior management has the primary responsibility, and as an activity that determines priorities, establishes a systematic framework for the company’s activities, and helps managers establish the overall direction of the company. Strategic planning involves creating a vision of the business the company is in or wants to be in, setting the company’s goals, and determining resource allocation and other actions to pursue those goals. The successful result of strategic planning usually is seen as maneuvering the company over the long run into the product and market positions and to the profitability levels desired vis-à-vis competitors.

During the 1950s, 1960s and 1970s many companies developed strategic planning
processes and methodologies that became increasingly elaborate and institutionalized as the companies grew in size and increased in complexity; Lorange and Vancil were among the apostles of this movement. Especially was this process important in large multinational companies, which encountered unprecedented complexity caused by differences among national environments and responded by attempting to coordinate operations on a global basis within these environments; Scott, for example, describes the coordination activities of these multinational companies. A major vehicle for this coordination was strategic planning, which received a great deal of management’s energy and attention in multinational companies of that earlier era.

Mintzberg states that since the mid-1960s when corporate leaders embraced strategic planning as the best way to devise and implement strategies, strategic planning has fallen from its pedestal; he attributes this to improper strategic planning. Whatever the reason, in the 1980s when the markets of many countries attached increased importance to higher quality and lower cost products, the emphasis shifted to manufacturing and operating efficiency, and to greater product quality. This has meant that management has given more attention to tools such as JIT, Kan Ban, Quality Circles, TQM, continuous improvement and similar tools, and this has shifted management attention away from strategy and strategic planning. In the pursuit of greater efficiency, companies also were downsized, right-sized and re-engineered, and the impact of these cuts was felt on the staff planning activities. The line and senior managers who remained devoted more attention to establishing lean operations and less attention to planning. It seemed to be presumed that much or most of the strategic planning activity was avoidable overhead.

Technology areas of the company, and in particular, the research and new-product development activities of technology companies, were not spared the downsizing and de-emphasis of strategic planning. At the same time, almost paradoxically there has been a surge of new and derivative technologies developed and the marketplace now expects ever more rapid introduction of an always increasing variety of high-tech products, as well as continuous improvement of existing products, all of which increase the complexity of high-technology product development. Further, in many areas of technology, longer and larger projects for future products are becoming the norm, increasing the overall long-term commitment of companies. The Iridium satellites-in-the-sky, a wireless telephone system introduced in November 1998 (and which subsequently has experienced financial failure), is but one example, required a mammoth capital investment and many years of development before its market debut. During the period of downsizing many companies decentralized R&D and product development to their business units in order to achieve a more direct and rapid link to business units’ customer needs, and to increase operating efficiency by eliminating or reducing the overhead of central R&D activities. The role of a central R&D activity was reduced and its cross-company planning and coordination role diminished. However the increased product and market complexity begged for more coordination, not less. For instance, more coordination among the business units was needed in order to increase cross-company technology exchange and product development synergy.

Additionally, the decentralization of R&D and other product development activities tended to place greater emphasis on shorter-term product development goals, consistent with the short-term business goals and normal operations of the business units. Business unit managers became more oriented to satisfying customer’s immediate needs and developing this years’ and next years’ new products, and were commensurately less interested in funding longer-term research to develop radical new products.

Sustainable advantage derives from positioning the entire company for the foreseeable
future, which involves evaluation of a range of long-term alternative strategies and election from among them. Companies that dismantle strategic planning and replace it with operations improvement techniques that provide a short-term assist are not easily able to make long-term strategic choices or fully appreciate what these choices are. These companies also seem less able to deal with the increasing complexity of business activities.

The research findings of this DELPHI study confirm the need for strategic planning, at least with respect to technology product development. The methodology of the study is explained below.

**Methodology of the Study**

The underlying methodology of the study is the DELPHI Questionnaire methodology. This methodology was originated by Helmer at the Rand Corporation and put forward by Linstone and Turoff, Bright, and others as a technology forecasting methodology. DELPHI forecasting methodology uses anonymous judgments of technology experts as provided by their responses to a questionnaire to examine the probable future directions of development of specific technologies or meta-types of technologies. The summarized judgments (in the forms of quantitative evaluations and written commentary) are provided as feedback to the same experts as parts of a ‘next-round’ questionnaire. The experts then reevaluate their opinions in light of this feedback, and a group consensus tends to emerge. Bright believes that technological forecasting, including DELPHI forecasting, is a form of logical analysis that leads to persuasive conclusions about future technological attributes.

Technology management problems do not closely fit with Bright’s description however, as these problems are not forecasts but instead are opinions about the present, and management problems are not ‘technological attributes’. The DELPHI forecasting methodology was adapted by Scott to become a ‘management problems’ methodology applied to International Accounting problems. In turn, subsequent researchers adapted Scott’s methodology for a series of DELPHI Questionnaire Issues studies in the area of information systems managers’ problems.

Scott continues this non-forecasting use of the DELPHI methodology, reporting results that serve as the basis of this article. Professional technology managers and academic researchers in the field of technology management participated in a DELPHI questionnaire management issues study directed to identifying and evaluating the unresolved categories of problems (meta-group problems) of management of advanced-technology product development. This study’s DELPHI methodology consists of a series of three questionnaires sent in succession to participants who are experts in technology management. For the final questionnaire, the participants are drawn heavily from attendees at International Association of Managers of Technology (IAMOT) conferences (the majority) who presented management-oriented papers, the authors of articles appearing in technology management, product development and management journals, and other experts suggested by participants in the prior two questionnaires. With each questionnaire the participants were requested to provide names of other experts who should be involved in the study.

The first questionnaire asks participants to evaluate a set of 59 management issues (unresolved management problems) with respect to the importance of each. The number of possible problems depends entirely on how many lesser or sub-problems are defined and presented as separate, possibly important, problems. Carried to the extreme, problem subdivision could provide an almost limitless set of problems, each requiring separate evaluation and collectively imposing a burden that potential participants would not
Accordingly, closely related sub-problems are combined into an overall problem, an approach widely used in DELPHI management problems research. Participants also are requested to provide comments about each problem with respect to why it is or is not important; these comments are forwarded to the experts as a part of the second questionnaire. Additionally, each participant is requested to suggest additional problems that are not yet a part of the study but which the participant believes to be important; these problems are included for evaluation with the next questionnaire to ensure that all possible technology management problems are identified and subsequently evaluated. A ranking system from 1 to 10 is used, with 10 being ‘most important’. The rank order of importance of each of the issues of this first questionnaire’s issues is calculated based on the statistical means of the participants’ scores for each issue. The same methodology is used with the second and third questionnaires.

The lowest-ranked problems on each of the first two questionnaires are not continued to the next questionnaire. The second questionnaire consists of the top thirty-one problems of the first questionnaire plus additional problems suggested by participants of the first questionnaire. Included are the evaluations (the mean score and standard deviation) from the first questionnaire for each of the 31 problems, as well as the comments of the participants about each problem. These forms of feedback from the first questionnaire influence participants to reconsider the importance rating they previously assigned to each problem in light of the feedback from the preceding questionnaire. They may then alter their evaluation of a problem in response to persuasive feedback, and they again provide commentary about the problem. A similar process is followed for the third questionnaire and this questionnaire too includes additional problems suggested by participants of the preceding questionnaire.

Of 63 responses received for the third, final questionnaire, there was a 56% response rate. Included among these 63 are 13 from the UK, 24 from the rest of Europe, and 22 from the USA. Of the participants 36 were academics researchers and 27 were technology managers in industry.

Based on the results of the third questionnaire, final rankings are established for the top 24 technology management problems. A movement toward a consensus (greater agreement) about the relative importance of the problems is observed for 20 of the 21 problems that were evaluated on both of the last two questionnaires. This tendency toward consensus is indicated by a smaller standard deviation for a problem after the third than after the second questionnaire. Among the additional problems submitted with the second questionnaire, three are evaluated high enough to be included among the top 24 and so are evaluated only on the final questionnaire. The analysis of the results of the third questionnaire serves as the basis of this article.

The advantages of this very time consuming series of sequential questionnaires include:

(a) Identification of All Problems. New problems are solicited from the participants with each new questionnaire, and participants willingly provide these. These additional problems then are evaluated as a part of the subsequent questionnaires. With this approach the probability is low that important problems will be overlooked, and the comments provided by the participating experts make it more likely that most of the important dimensions of a particular problem are given consideration by other participants.

(b) Greater Consensus. While the evaluated score of each issue may change from one to the next questionnaire, the agreement among the participants about the relative importance of most problems increases. This is because the feedback provided with each questionnaire about each question tends to convince participants to view the problem similarly.
(c) Thoroughness. Participants evaluate the problems multiple times and each questionnaire along with the discussion comments from each provides additional insights into the problem area as well as greater confidence in the results. Because of this, superficial views are not as likely to prevail as with a ‘one shot’ questionnaire. This thoroughness provides greater confidence to the participants and to the later readers of the study that the results are reliable, in part because it is clear that all participants’ views on the problem are considered by all other participants.

Findings of the Study

The 24 highest ranked problems are shown in summary form in Appendix I. The means shown there are equally weighted for practicing technology managers and for academic researchers as separate groups. The complete findings of the study are reported in detail in other articles.13 These findings are summarized below.

• One issue, strategic planning for technology products, reigns supreme as the most important problem.

• Academic participants (57% of the total) and technology managers in industry differ markedly with respect to their evaluations of certain issues. Especially, academic researchers in technology management evaluate organization learning about technology (Appendix I, Problem 3) more highly than do practitioners, and the reverse is true for creating a conducive culture (Problem 6). While no evidence provided by the participants’ responses explains the divergences between the groups, it can be speculated that at the time of the study company managers did not think in terms of organizational learning (Problem 3) whereas this was already a recognized research area for academics. Corporate culture problems (Problem 5) on the other hand are observed every day by technology managers but are nearly transparent to persons such as academics who are outside of a company. Problem 8 pertaining to detecting and evaluating technology trends and paradigm changes also shows a significant difference between these groups, with practitioners ranking it lower in importance; no direct reason for this is seen in the study results although conjecture suggests that major trend and paradigm changes are only very occasional phenomena that are somewhat distant from technology managers’ day-to-day activities.

• The study’s results appear to have important implications for additional research, for practice development, for corporate technology managers who wish to evaluate or improve their company’s technology management, and for curricula in the management of technology and business/management areas.

• The problems are interrelated. Many participants’ comments state that a particular problem is related to another problem, and then explain why.

Given the primacy of the problem of strategic planning for technology products, it is this last finding about the interrelationships of the problems that provides the impetus for this article. Many of the participants’ comments note the relationships of others of the problems to strategic planning for technology management. This suggests that this top problem also may be a key to dealing with several of the other problems. It follows that careful attention to this problem area by company managers as well as by academic researchers can assist with the resolution of many other problems. This most important problem is examined below.

Strategic Planning for Technology Products

This problem is stated below as it appeared on the last two of the three DELPHI questionnaires, with only minor changes from the first questionnaire.
Strategic Planning for Technology Products. Issues associated with strategic and long range planning for technology-product development, such as aligning high-tech strategies with business strategies (or vice versa if the technology strategy should be dominant), new product introduction strategies, strategic decision-making processes, lack of understanding of technology and its roles among corporate strategic planners, lack of coherent corporate level planning for high-tech management, failure to identify the critical success factors of a company’s technology activities, and establishing the corporation’s technology climate.

Evaluations:

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<th>Academic participants’ average</th>
<th>Industry participants’ average</th>
<th>Overall average</th>
<th>Overall standard deviation</th>
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<tr>
<td>Academic participants’ average</td>
<td>8.000</td>
<td>8.360</td>
<td>8.180</td>
<td>1.589</td>
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Relative to the other 23 ranked issues, this problem is clearly dominant. The following indicate this dominance:

(a) Both academic researchers and professional managers rank the problem as the top problem of high-tech product development.
(b) The problem is evaluated as the most important problem on all three of the questionnaires (only in the last questionnaire was it listed first).
(c) The margin between this problem’s evaluation score and that of the second-ranked problem is greater than the margin between any other two problems in sequence.
(d) The problem is ranked first in importance by UK participants, first by other European participants, and first by American participants (with scores of 7.923 for UK, 8.200 for US, and 8.167 for European participants).

The participants’ comments about this problem also are more voluminous than about any other. Many of the comments can be classified into one or another of a small number of patterns. The most frequent comments suggest that this strategic planning problem in technology management is related to a company-wide strategic planning problem. Some of the technology management experts state their belief that too many high-tech companies give little attention to preparing a company-wide strategic plan, to implementing the plan, and then to pursuing the plan after its implementation.

A few comments fit into a related pattern to the effect that although company strategic planning does not seem particularly effective overall in many companies, strategic planning for technology products usually is even less effective. Some of the aspects of poor strategic planning are viewed as primarily applicable to technology management strategic planning. One is that even if companies have a strategic technology plan, they may abandon part of it in order to pursue a perceived short-term new product opportunity. This is directly contrary to a ‘best practice’ of technology management that companies should continue to pursue existing resource strategies rather than changing strategies.

Another pattern among the comments is the participants’ stated belief that strategic plans for technology should be congruent with corporate strategic plans, but too often are not. Metz discusses this aspect of the problem with respect to integrating technology planning with business planning, although Metz’s discussion does not distinguish between tactical and strategic planning. Another particular concern for the experts of this DELPHI study is their belief that congruency often is not achieved because corporate strategic plans tend to be for shorter periods of time—perhaps for five years—whereas many new product development projects extend for a decade or longer and encompass the period...
required to undertake R&D and then take a new product through the subsequent development processes. This temporal mismatch can be of even greater concern if the development activity is under the jurisdiction of business units (as is very frequently the case) because business units tend to place emphasis on shorter term results and shorter term projects than do corporate levels and so may have little tolerance for new projects with long horizons. As will be seen with the discussion of some of the following problem areas, this concern about the short-term perspectives of non-technology groups is pervasive in many dimensions of product development.

Another set of participants’ concerns about strategic planning for technology products centers on plan implementation, a topic that receives little attention in the technology management literature. The comments indicate that in some companies with satisfactory technology strategic plans it is the implementation of the plans that fail. As inferred by comments about others of the problems that do not make specific reference to plan implementation, the reasons for this implementation failure may include a lack of commitment by senior management, failure of a project to acquire a sponsor or champion, a lack of understanding by technologists about how to implement plans, failure to adequately fund an existing plan, or political conflicts within the company that place the plan in jeopardy.

No pattern emerged in the study’s findings with respect to assigning blame to any group for the problems of strategic planning for new-technology products. Although many participants’ comments about the eleventh-ranked problem, senior manager involvement, say that some senior managers may not be sufficiently knowledgeable about the company’s technologies, almost no participants placed the blame for technology strategy problems on either corporate or business unit senior managers. This seems an anomalous result, considering that strategic planning for technology is seen as the most critical problem of new product technology management and that this strategic planning is considered by the participants to be the responsibility of senior managers.

The premier importance among technology management problems problem of strategic planning for technology products does not appear to have been established explicitly in the research literature. Several research studies have focused on ‘best practices’ and several on ‘critical success factors’ in technology management, and certain of these studies involve development of technology products while others are devoted to development of products without regard to their degree of technology intensity. Certain of these studies mention strategy or strategic planning in the context of several other best practices or critical success factors, but none appear to select strategy or strategic planning as being of preeminent importance for either high-tech product development or non-technology product development. Menke, for example, in a study devoted to R&D ‘strategic excellence’ lists as one of ten best practices the need to frame R&D decisions strategically. That study does not examine the extent to which best practices are followed or not followed, i.e. the extent to which the area of a best practice remains as a problem for companies.

In another study involving a sample of ‘best companies’ Menke’s findings seem consistent with the possibility of strategic planning for technology products being an important problem. He states as ninth in rank out of ten that the best practice of ‘coordinate long-range business and R&D Plans’ is the least ‘actualized’ (the least implemented and adhered to) among the 10. In this context the term ‘coordinate’ appears to mean the linkage of the plans, which is one of the several dimensions of the problem of strategic planning for technology products.

A study about critical development activities identifies a gap between current and best practices with regard to emphasis on strategic planning for ‘radically new’ product development. The findings indicate that a relatively low level of proficiency in strategic planning activities exists for ‘really new’ products (these ‘really new’ products are not
identified as embodying advanced technology). This finding seems consistent with this DELPHI study’s finding about the importance of the problem area of strategic planning for technology products but is not focused on technology products.

The importance of strategic planning has been explicitly established in a field other than management of high-technology product development: like the present study, the methodology used also was DELPHI. Beginning in 1984 and continuing through 1996 (prior to the emergence of the World Wide Web) a series of four DELPHI studies were done to assess the importance of the problems faced by information technologists of companies. Each of these studies was, in effect, a continuation of the last study, and each ranked 18 to 20 information systems issues. The first of these studies (1984) ranked ‘Long range planning and integration’ as the number one problem. The second (1987) placed ‘Strategic planning’ in the top position. The third study (1991) ranked the issue of ‘Improving strategic planning’ as third in importance and the fourth study (1996) ranked this same issue tenth.

Relationships of Other Problems to Strategic Planning for Technology Products

The preceding discussion establishes the problem area of strategic planning to be the premier technology management problem. Respondents’ comments suggest that others of the high ranking problems are related to the strategic planning for technology products problem, opening the possibility that attempts to deal with other problems may impact the strategic planning problem. If others of the problems can be shown to be closely related to the premier problem, this finding may be of key importance to companies as well as researchers because it suggests that perhaps remedial/improvement initiatives should deal with multiple problem areas simultaneously. The focus of most of the remainder of this article’s discussion explores this possibility by examining the inter-relationships of each of the next 10 problems (those ranked 2–11 in importance) to the strategic planning for technology products problem. Space limitations prevent the discussion of the final thirteen problems.

New Product Project Selection, and Strategic Planning for Technology Products

This new product project selection problem ranks second in importance among the 24 problems. As with the next nine problems the discussion is focused on linking each to the top problem of strategic planning for technology products. A broader discussion that includes other aspects of the participants’ comments about each problem is found in Scott. This issue is stated fully below. A study by Cooper, Edgett and Kleinschmidt supports the evaluation of project selection as being of high importance.

New Product Project Selection. Issues involved with high-tech new product development project selection; e.g. the criteria (costs/benefits, strategic necessity, etc.), how to establish a systematic approach to selection, inability of conventional financial analysis criteria to evaluate the potential of radical new technology, etc.

Evaluations:

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<th>Academic participants’average</th>
<th>Industry participants’average</th>
<th>Overall average</th>
<th>Overall Standarddeviation</th>
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<tr>
<td>New Product Project Selection</td>
<td>7.355</td>
<td>7.240</td>
<td>7.297</td>
<td>1.473</td>
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These authors note that managers are generally displeased with or doubtful about the processes of selecting projects for their new product portfolio, which clearly argues for the importance of this as a problem area. These authors also cite a difficulty as being the linking of goals and strategies to R&D projects, which establishes a relationship to the top problem of strategic planning for technology products.

The major concern of this DELPHI study’s participants is the perceived dominance of ‘conventional financial criteria’ for evaluation of potential new projects, such as rate of return, discounted cash flow, and payback period evaluation methodologies. These criteria are viewed as introducing a short-term bias to technology product project selection. The participants argue that, especially when research for a product is in an early stage, the potential of the new product or product set often cannot be adequately evaluated with financial criteria. As an example, a concern of the respondents is that projects with a payback of three years rather than ten years will be selected even if the longer payback project ultimately will have a much higher payoff, or will increase market share, or will forestall a competitor’s entry into the market, or even will create a new market sector.

Pavitt expresses a concern about financial appraisal techniques. He believes that ‘the uncritical application of conventional project appraisal techniques will result in myopic technology strategies’ because these conventional financial criteria neglect the benefits from a project of acquiring knowledge that subsequently can be used to exploit other opportunities.25

The clear sentiment expressed by the DELPHI study’s participants is that other non-financial criteria should be weighted heavily in some circumstances such as when the prospects of a particular new product can be only dimly perceived. One reason why financial methodologies are emphasized may be that they are widely known and are already accepted and used for other purposes in most companies. Thus, these methodologies are immediately available to fill a void that exists because there is no generally accepted methodology that identifies the circumstances when reliance on financial criteria should be avoided or that specifies preferred alternative criteria in particular circumstances.

Broader frameworks are available for technology project evaluation, and they should be considered for use during technology strategic planning activities. A first consideration is that a particular project should be viewed as one project of a long-term portfolio of projects that is constructed in concert with strategic planning for technology, especially if other potential and existing products of the portfolio can gain synergies from a newly selected project. These synergies are unlikely to be easily measurable, but usually can be better portrayed using investment portfolio concepts of risk and return tradeoff than by using only financial criteria. If the technology project portfolio is based on strategic considerations developed during technology strategic planning in order to provide the needed balance to the portfolio, both short and long term considerations will become a part of the portfolio’s balance.

Metz ties project selection to strategic planning by suggesting a balanced technology portfolio as a part of establishing a structured process for technology strategic planning. This strategic planning structure should include creating a technology vision and defining the company’s technology options that could contribute to establishing a competitive advantage.

Thus, a balanced portfolio of technology projects should be developed and evaluated as an integral part of strategic planning activities. Evaluated together, short-term, longer-term, and technologically risky projects can all be seen as mutually supportive and as elements of overall technology and corporate strategic plans. Even the technology groups of companies with meager or no corporate strategic planning can produce technology project balanced portfolios as a part of technology strategic plans, and this may assist with overcoming the short-term bias in technology project selection.
Some companies have developed project selection methodologies that are candidates for ‘best practices’. Motorola Communications, for example, did not rely on projections of financial returns and on discounted cash flow analysis in making a decision to proceed with development of cellular telephones, a product that Motorola invented. For radical departures from existing technologies Motorola places new projects within a ‘strategic framework’ and ‘listens to collective judgement from a lot of people who have been around a lot of years and who have made pretty good judgements and who understand the technology and the markets’. The decision process uses a context of ‘Does the opportunity fit within the strategic focus of the business?’; ‘Does the business have a distinctive competence with respect to the opportunity?; and ‘Is the opportunity . . . substantial enough to merit the risks and resources that need to be devoted to it?’.

For project decisions within existing product lines Motorola uses a technology strategic roadmap process. Each line of business creates a ‘roadmap’ for its technologies for the next five to ten years. Each business unit also agrees to technology and product development objectives that are consistent with the long-term roadmap; these objectives are based partly on financial criteria.

Cooper, Edgett and Kleinschmidt make recommendations about technology project portfolios. They recommend that resource allocations between business units be within and a part of the corporate planning process. They also suggest that business units produce their own new product strategy using a roadmap process that drives new products from idea to launch (for example, a stage gate process). These authors recommend use of a scoring model but warn that financial analysis methods pose problems. Their final recommendation is a review process that holistically considers all projects together. Three models are considered for this portfolio review, one of which is a ‘strategic alignment’ model; collectively these models provide a portfolio that meets a company’s strategic plan goals for new products.

Another general approach to technology project selection, compatible with technology road maps, is systematic monitoring of technology risk. If a risk monitoring system is in place it is likely to be an integral part of technology strategic planning and new project portfolio development activities. Such a system can provide accurate assessments of technology and development trends, which can assist with building and supporting technology roadmaps that are included as a part of technology strategic planning.

Organizational Learning and Technology Strategic Planning

This third-ranked issue is shown below.

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<th>Organizational Learning About Technology</th>
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<td>7.935</td>
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Two major concerns are expressed by both technology participants and academic participants. The first is that companies often have no mechanisms or systems to organize and retain the knowledge of technologists, which is especially critical if the technologists leave the company. The second is how to know who within a company possesses what knowledge and experience so that a full range of both formal and tacit knowledge can be brought to bear on a new project, particularly in organization units different from the ones in which the knowledge reposes. Organizational learning is a topic frequently dealt with in the literature.\(^{30}\)

Technology strategic planning should play multiple roles with respect to resolving this organizational learning issue. One role is that of allocating resources to an internal group for the development of a formal technology knowledge repository. This repository development might be a staff activity within a central R&D group, or it might be the task of a company’s human resources group.

The technology strategic plans also should provide for and support technology diffusion programs, such as education and training seminars that inform technologists about the knowledge in the knowledge repository and inform them of their responsibilities for contributing knowledge to that repository. Pavitt has noted that knowledge gained through experience is partly tacit and that personal contacts and discussions are an effective means of diffusion of tacit technology knowledge.\(^{31}\)

Strategic planning for technology products should encompass several organizational learning considerations. Clarke believes that the formation of a knowledge strategy is critical and notes that some companies have appointed chief knowledge officers.\(^{32}\) Clarke suggests that companies begin by developing sophisticated scenarios related to the knowledge portfolio that will be needed to compete in the company’s potential environments, then develop a business strategy related to accumulating the knowledge that will be needed. Presumably, this strategy should be an integral part of the technology strategic planning activity, with the planning results becoming integral components of the technology and the corporate strategic plans.

Additional attention given to new product development within the strategic plans, at both the corporate and business unit technology management levels, should include attention to which organizational learning activities should be centralized at the corporate level and which decentralized to individual business units or networked among business units. The structure chosen should be effective for ensuring that both formal and tacit knowledge is gathered and stored, in a manner that helps to make the existence of this knowledge known and to make the knowledge available to all technology groups within the company.

Bartlett and Ghoshal make a direct connection between organizational learning and strategic planning although without specific reference to technology management.\(^{33}\) They suggest that strategic planning and organizational learning are merging, with strategic planning of the past evolving into an era of organizational learning. They believe this will happen as companies try to be sensitive to emerging changes in their environments and attempt to quickly capture knowledge about these changes as a part of organizational learning. Certainly, such a development would establish a linkage between this, the third-ranked problem and the premier problem of strategic planning for technology products by making them indistinguishable from one another.

Technology Core Competencies, and Strategic Planning for Technology Products

The technology core competencies issue, below, is ranked fourth in importance.
**Technology Core Competencies.** Issues involving identification and development of technology core competencies.

Evaluations:

<table>
<thead>
<tr>
<th></th>
<th>Academic participants’ average</th>
<th>Industry participants’ average</th>
<th>Overall average</th>
<th>Overall standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.000</td>
<td>7.440</td>
<td>7.220</td>
<td>1.710</td>
</tr>
</tbody>
</table>

The major concern of participants is that the concept of core competencies and the application of this concept to technology management remains ill-understood. Perhaps this is because a concern that explicit attention be given to developing core competencies has emerged recently enough that little attention has yet been devoted to core competency development processes in the specific field of technology management.  

The expert participants also note that in many companies core competency development activities are not as yet institutionalized or championed for technology activities. This lack of previous emphasis makes core competency building vulnerable to short term opportunities favored by the business units, as well as to internal political maneuvering. In turn, this suggests the importance of explicitly providing for these activities during strategic planning. The approaches already examined for incorporating project selection into strategic planning in ways that reduce the short-term orientation of the business units with respect to project selection also seem relevant to overcoming the vulnerability of core competency development to short-term opportunities.

The linkages between the preceding problem of organizational learning and the present one of core competency development seem clear. Knowledge about both formal and tacit core competencies represents a form of knowledge that should become a part of organizational learning. Accordingly, the discussion about the relationship of organizational learning to strategic planning for technology products seems almost equally applicable to core competencies. Attention should be devoted at the same time to these two somewhat intertwined issues by strategic planners, technology managers and academic researchers.

Strategic planning should allocate resources for core competency development, play a major role in institutionalizing core competency dimensions of technology management, and help to inculcate core competency thinking into the fabric of the corporate culture. Klein makes the case for a linkage between strategic planning and core competencies by stating that when a company’s managers ask what the company’s products should be, they also should ask what technology competencies the company should be building now to provide for long-term strategies. Core competencies usually take many years to build, which requires a long term perspective, and strategic planning activities for technology core competencies usually should have a longer time horizon than even the corporate strategic planning horizon.

**Cycle Time Reduction, and Strategic Planning for Technology Products**

The dominant theme of concerns about this cycle time problem (ranked fifth and shown below) is that while both the theory and practices of cycle time acceleration are well known to companies, it remains difficult to implement improvements to cycle times.
**Cycle Time Reduction.** Issues about accelerating new product development cycles (cycle time reduction); e.g. limitations of cycle speed benchmarks, making concurrent engineering work, the virtue of using cycle speed to permit a later start on product development (in order to capture the most current technologies and customer needs) rather than to introduce new products sooner.

Evaluations:

<table>
<thead>
<tr>
<th></th>
<th>Academic participants’ average</th>
<th>Overall average</th>
<th>Industry participants’ average</th>
<th>Overall standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.032</td>
<td>7.076</td>
<td>7.120</td>
<td>1.553</td>
</tr>
</tbody>
</table>

Developing a cohesive and comprehensive strategy for cycle time reduction as a part of the technology strategic planning activities may help to establish cycle time reduction as a program activity and as a high priority task. Specific product development cycle time reduction methodologies can be included as a part of the strategic plans. One advantage of these is that as part of the strategic plans, the cycle time reduction activities are less likely to fall prey to short term opportunities.

**Creating a Conducive Culture, and Strategic Planning for Technology Products**

This sixth-ranked problem, shown below, can be dealt with to a great extent with improved technology strategic planning.

**Creating a Conducive Culture.** Issues having to do with creating a corporate culture conducive to high-tech new product development; e.g., establishing an internal sharing and informal networking culture, reducing within-company rivalries, gaining full cooperation of all groups in the company, giving recognition to the importance to the company of new product development, and elevating the importance of scientific and technical personnel.

Evaluations:

<table>
<thead>
<tr>
<th></th>
<th>Academic participants’ average</th>
<th>Overall average</th>
<th>Industry participants’ average</th>
<th>Overall standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.806</td>
<td>7.063</td>
<td>7.320</td>
<td>1.734</td>
</tr>
</tbody>
</table>

A recurring theme among the expert participants of this study is that improving the culture climate for technology development is critical but that satisfactory results are elusive. In part this elusiveness is because the culture-improving processes involve attention to many dimensions of an organization. Further, the experts’ comments indicate a belief that ultimately major improvements must be the consequence of senior management initiatives as well as subsequent follow through by the senior managers. This senior management involvement is essential for demonstrating a continuing commitment to culture aspects of technology intensive product development activities.

Many of the culture improvement initiatives (such as policies that ensure that champions of failed new technology product development projects will not be punished) should be established as a part of the technology strategic planning activity. Perhaps as
important, or more so, is senior management’s insistence that activities and policies related to culture and that are intended to promote technology development be framed within the corporate plan and linked to the technology plan. This demonstrates to technologists and project managers alike that senior management is attempting to establish a technology-friendly culture. Follow-ups on the part of senior management are necessary.

As a part of this technology-friendly culture activity, senior management also should employ mechanisms to change the culture of the rest of the organization to one that is receptive to viewing technology as critical to the company’s competitiveness. This will help promote company-wide cooperation with the technologists and will build their self-esteem, itself a part of improving the culture for technology.

New Product Development Teams and Strategic Planning for Technology Products

The major concern of participants with respect to the seventh-ranked issue of coordination and management of product development teams, shown below, is that although the theory and techniques are known, too many companies nevertheless have ineffective teams.

<table>
<thead>
<tr>
<th>Coefficient and Management of New Product Development Teams.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issues surrounding new product development team structure, team size, membership composition of teams, team operations, team leader selection, need to train teams in teamwork and conflict resolution, team management, inter- and intra-team coordination, team control and evaluation, team reward structures, team motivation, team member access to project databases, and types and structures of communications systems needed by teams.</td>
</tr>
<tr>
<td>Evaluations:</td>
</tr>
<tr>
<td>Academic participants’ average</td>
</tr>
<tr>
<td>Industry participants’ average</td>
</tr>
</tbody>
</table>

High performance teams for high-tech products require several ingredients. One is that the team leader must be a genuine leader. Another is a lengthy learning period of operating as a team. Also, a company’s culture must encourage team operations and the performance evaluation structure must stress rewards for teamwork and collaboration.

All of these ingredients can be linked to technology strategic planning. Corporate and business unit strategic planning should deal with providing for the needed evaluation and reward systems for technology teams, with committing adequate resources for team training, and with team structure such as providing for technologist and non-technologist group interaction in teams. The technology strategic plan also can articulate the policies for the reward structure.

The strategic plan can have a major influence on team effectiveness by emphasizing in its articulated policies that senior management is committed to entrepreneurial innovation through the use of teams. As examples, the strategic plan can establish the conditions under which teams will operate, and can assign specific long-term development projects to particular teams. The technology strategic plan also can establish, via the
project organizational arrangements, whether each team is going to be a ‘heavyweight’ team or will use another team structure.36

Technology Trends/Paradigm Shifts and Strategic Planning for Technology Products

The DELPHI expert participants’ major concerns about this eighth problem (below) of not giving careful attention to paradigm shifts and to monitoring technology trends revolve around this being an unnatural activity for technology researchers and technology managers.

Technology Trends and Paradigm Shifts. Issues pertaining to detecting and evaluating technology trends and paradigm shifts and convincing the company that these shifts require dramatic repositioning of the company’s technology posture, as well as to the acceptance in the marketplace of particular technologies and the future need for new kinds of products that customers do not yet say they need; e.g. the nature and structure of technology scanning and intelligence systems for early warnings, technology forecasting, and analysis methodologies to demonstrate eventual impact on the company of a paradigm shift.

Evaluations:

<table>
<thead>
<tr>
<th></th>
<th>Academic participants’ average</th>
<th>Overall average</th>
<th>Overall standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic participants</td>
<td>7.387</td>
<td>7.034</td>
<td>2.173</td>
</tr>
<tr>
<td>Industry participants</td>
<td>6.680</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Technologists are preoccupied with technologies of today with which they are in intimate contact on a continuous basis. This makes it difficult for them to think about how technologies will evolve or how new technologies will emerge to replace technologies now used by the company. This concern expressed by the study’s participants suggests that the use of technology road mapping should be embraced by more companies, and that the road maps should give attention to both technology trend analysis and to possible paradigm shifts that could impact the company.37 The strategic planning activity should anoint, formalize, and encompass the medium- and distant-future results of this technology road mapping.

Cross-Functional Participation and Strategic Planning for Technology Products

Issues nine and ten, shown below, both deal with providing for the participation in the product development processes of persons who do not directly develop the product technology or manufacture the product. A related issue (not shown here) that is ranked much lower is issue number 17, involvement of manufacturing in the product development processes. With all three issues the major concern expressed by the comments of the DELPHI participants is how technology managers should ensure the inclusion in new product development activities of all parties with a stake in the high-tech product being developed.

Technology strategic planning can address this concern by including within the plan policies that enunciate the requirement for cross-functional participation and, at least for the more important teams, can establish which groups will participate in each stage of each
technology product development project. In part this is likely to entail the specification of the organizational units that will participate and of the responsibilities of each for a project team.

**9. Involvement of Marketing Groups.** Issues about the involvement of marketing, market research and customer service personnel in new product development, such as their participation in selecting research and product development projects, identifying customer needs, defining the market timing the introduction of new higher-tech products that will make the company’s existing products obsolete, establishing the high-tech product family mix, and accelerating feedback from the marketplace about customer satisfaction with the newest high-tech products.

Evaluations:

- Academic participants’ average 7.122
- Industry participants’ average 6.727
- Overall average 7.010
- Overall standard deviation 1.500

**10. Customer/Supplier Involvement.** Issues about whether and how to involve customers and/or suppliers in new product development; e.g. how can collaborating vendors be prevented from passing new technology developments along to their other customers, circumstances in which suppliers should develop prototypes for the company or should be restricted to contractual arrangements based on technical specifications, and a need to help suppliers upgrade their capabilities so they can better assist the company.

Evaluations:

- Academic participants’ average 7.133
- Industry participants’ average 6.800
- Overall average 6.967
- Overall standard deviation 1.585

**Senior Management Involvement and Strategic Management of Technology Products**

Although senior management is the driving force behind strategic planning, their involvement is ranked only eleventh as a problem (the issue is stated below).

**Senior Managers’ Involvement in Technology.** Issues surrounding corporate senior managers’ interaction with high-tech product development, such as a need for senior managers to understand their company’s technology, a need for their long-term commitment, a need for champions and sponsors for technology projects and embryonic products and product lines, and the need for senior managers to take the lead in creating the corporate culture needed.

Evaluations:

- Academic participants’ average 6.968
- Industry participants’ average 6.905
- Overall average 6.936
- Overall standard deviation 1.802
Most of the comments are about the need for senior managers to understand technology at least well enough to plan strategically for it, which emphasizes the relationship of this problem to technology strategic planning. Several comments are to the effect that senior management participation with respect to technology is actually a strategic planning and a leadership issue, and that technology strategic planning is the direct responsibility of senior management.

This suggests that this ‘senior management’ problem is quite different from the problems already discussed. While the other problems are related to and can be assisted by technology strategic planning in the many ways examined, the senior management problem is in part a cause of the technology strategic planning problem. Thus it can be argued that is not possible to conquer the technology planning problem without dealing with the senior management problem, as technology planning requires the participation and cooperation of the senior management of a company. Accordingly, the first item on an agenda to deal with the strategic planning for technology products problem should be that of gaining the cooperation and active participation of senior management.

Other Related Issues

Certain of the remaining thirteen issues also are related to strategic planning for technology Products. Several comments about issue number 16, using high-tech for competitive advantage, are to the effect that a technology-based competitive strategy must be developed if technology is going to provide a competitive advantage. Issue number 19, resource allocations to high-tech activities, also is said by participants to be related to technology strategic planning and to strategic management of technology, although no specific relationships are cited. Several participants note that issue number 20, establishing a technology vision, is actually a sub-problem of strategic planning for technology products.

Implications of the DELPHI Study’s Findings

In the companies of many industries the primary basis for competition has become that of advanced-technology products. Yet, there are grave doubts about the effectiveness of many companies’ technology management. For example, a survey of more than a decade ago of 1500 chief executive officers of US companies indicated that, by a good margin, the most important reason that US companies lost competitiveness in the international marketplace in the late 1980s is that ‘executives have not properly managed technology’. 38 Has the situation improved enough since? In terms of the quality control concept of ‘continuous improvement’, doubtless even substantial improvement to this time would mean that still more improvement is needed. With technology as an important basis for competition, and improvements in technology management needed, it is necessary to establish what areas of technology management involving new product development in companies are in greatest need of improvement. When this is accomplished attention can be directed to the most critically important of these problem areas. To establish which areas need improvement requires first that the problem areas be identified. This DELPHI study identifies these problem areas and also ranks them in order of importance. The discussion of this article directs attention to the most important 24 of these.

A signal discovery this DELPHI study is that many of the high ranked technology management problems of product development are associated with or in part subsumed by the highest ranked problem. This suggests that attention to reducing the severity of this top problem is also useful attention to many of the other problems deemed important.
Equally important is that dealing effectively with the top problem probably requires a coordinated program that also recognizes and deals with those aspects of the other problems that are related to the top problem, such as those shown by the discussion of this article. Thus the problem areas as stated in the DELPHI study, while separate, are nevertheless related. Remedial or improvement activities that are narrowly focused on the top problem seem unlikely to be fully effective.

Similarly, academic research that examines the top problem of strategic planning for technology outside of the context of the other problems seems unlikely to be fully effective.

An approach suggested in the article is that of focusing effort on this most important problem of technology strategic planning. This will have the effect of dealing simultaneously with some aspects of the next several problem areas.

The senior management of companies is named as a problem in issue number 11; senior management can reduce itself as a problem by giving its attention to strategic planning for technology products. Dealing with this problem area is a normal part of senior management’s leadership responsibility.

**Summary and Conclusions**

A DELPHI management issues investigation that identifies and evaluates the importance of 24 management problems of product development in high-tech companies is described, and strategic planning for technology products is shown to be the most important problem of these 24.

The next ten new-product development problems of high-tech companies are examined in the context of this most important problem, and each is shown to be related to the top problem of strategic planning for technology products. The discussion of the article serves to embed strategic planning palliatives deeply and in multiple ways into the fabric of the other problems evaluated by the study and so further emphasizes the importance of this top problem. It is suggested that by directing attention to technology strategic planning a company can and should deal simultaneously with many aspects of the next ten most important problems of high-tech product development.

There is ample scope for companies’ remedial programs and for academics’ research programs to take any of several directions. Efforts may focus directly on the central problem of strategic planning for technology products, as an example. Or, programs can address one of the major secondary problems discussed, being certain to account for how the problem is interrelated with technology strategic planning; the expectation would then be that via this problem by problem approach strategic planning for technology products also would be improved.

Another approach could be to select related sets of problems (again giving attention to how they are interrelated with the central problem) and devote attention to all of the problems of the set together. As examples, organizational learning and core competencies improvement (problems three and four) are related and can be addressed together. Similarly, cycle time reduction and improving project teams (problems five and seven have elements in common. So too do problems nine and ten. Each set of problems addressed by a company or a researcher can only be fully dealt with within a context that includes attention to strategic planning for technology products. Which approach is taken and which problems are addressed by a particular company or researcher depends on the circumstances.

Either of two broader scope problems also can be dealt with by an academic research project. The first is the extent to which strategic planning considerations are a critical problem in most fields of technology management, and the educational system and
practical implications of the findings. The second broad-scope research program could deal with what are or should be the ‘best practices’ of companies with respect to strategic planning involving advanced technology products.

**Notes and References**

7. Porter, op. cit., Ref. 5.
9. Ibid.
20. Dickson et al., op. cit., Ref. 11.
22. Niederman et al., op. cit., Ref. 11; Branchau et al. (1996), op. cit., Ref 11.
28. Cooper et al., op. cit., Ref. 24
32. Clarke, op. cit., Ref. 30
Appendix 1. Results of the DELPHI Questionnaire Study of Management of Technology Issues: Twenty-Four Technology Management Problems in Rank Order of Importance

*Note:* The overall average shown for each issue is the average of the two averages of academics and industry participants (i.e., despite differences in the number of participants in each category, each is weighted equally in determining the overall average). The overall standard deviation, however, represents the extent of variation among *all* participants.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Problem Description</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strategic planning for technology products</td>
<td>8.180</td>
</tr>
<tr>
<td>2</td>
<td>New product project selection</td>
<td>7.297</td>
</tr>
<tr>
<td>3</td>
<td>Organizational learning about technology</td>
<td>7.288</td>
</tr>
<tr>
<td>4</td>
<td>Technology core competencies</td>
<td>7.220</td>
</tr>
<tr>
<td>5</td>
<td>Cycle time reduction</td>
<td>7.076</td>
</tr>
<tr>
<td>6</td>
<td>Creating a conducive culture</td>
<td>7.063</td>
</tr>
<tr>
<td>7</td>
<td>Coordination and management of new product development teams</td>
<td>7.056</td>
</tr>
<tr>
<td>8</td>
<td>Technology trends and paradigm shifts</td>
<td>7.034</td>
</tr>
<tr>
<td>9</td>
<td>Involvement of marketing groups</td>
<td>7.010</td>
</tr>
<tr>
<td>10</td>
<td>Customer/supplier involvement</td>
<td>6.967</td>
</tr>
<tr>
<td>11</td>
<td>Senior managers’ involvement in technology</td>
<td>6.936</td>
</tr>
<tr>
<td>12</td>
<td>Soft skills for technical personnel</td>
<td>6.912</td>
</tr>
<tr>
<td>13</td>
<td>Organization structure for R&amp;D</td>
<td>6.857</td>
</tr>
<tr>
<td>14</td>
<td>Alliances/partnerships between technology companies</td>
<td>6.757</td>
</tr>
<tr>
<td>15</td>
<td>Within-company technology diffusion and transfer</td>
<td>6.732</td>
</tr>
<tr>
<td>16</td>
<td>Using high-tech for competitive advantage</td>
<td>6.644</td>
</tr>
<tr>
<td>17</td>
<td>Involvement of manufacturing in new product development</td>
<td>6.639</td>
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<tr>
<td>18</td>
<td>Globalization of product development processes</td>
<td>6.555</td>
</tr>
<tr>
<td>19</td>
<td>Resource allocations to high-tech activities</td>
<td>6.352</td>
</tr>
<tr>
<td>20</td>
<td>Establishing a ‘technology vision’</td>
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<tr>
<td>21</td>
<td>Productivity of product development activities</td>
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<td>22</td>
<td>Rewarding and educating technical personnel</td>
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<td>Project continuance/discontinuance</td>
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<tr>
<td>24</td>
<td>Oversight of high-tech activities</td>
<td>5.627</td>
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