

考試科目	經濟學	所別	科研所(甲)	考試時間	3月20日(上)午第1節 星期日
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國立政治大學圖書館

一、(10%)爲什麼一般而言水比鑽石便宜？請用圖形說明。水有比鑽石貴的時候嗎？

二、(20%) 河流的上游有一養豬場，下游有一遊樂場。Q 是養豬的頭數，養豬的邊際成本是 $MC = Q$ ，邊際效益 $MB = 60 - Q$ 。遊樂場因著豬場排出的污水所要負擔的邊際處理成本是 $SMC = 2Q$ 。請問：

- (1) 如果養豬場只考慮自己的利益，他會養幾頭豬？
- (2) 如果同時考慮遊樂場所受到的影響，應該要養幾頭豬？
- (3) 如果將河流的水權判給養豬場，依據寇斯定理(Coase Theorem)，在交易成本可忽略的情況下，養豬場會養幾頭豬？爲什麼？
- (4) 同理，如果將河流的水權判給遊樂場，養豬場會養幾頭豬？爲什麼？

三、請解釋以下名詞並舉例：(30%)

進入障礙，套牢，轉換成本，網路外部性，規模經濟，搭售

四、(20%) 請自行設定賽局報酬矩陣，以

- (1) 說明「囚犯困局」的現象。
- (2) 說明「爲何人人都不喜歡污染，但是自利的人卻還是會丟垃圾？」
- (3) 說明「爲何科技創新對整個社會有好處，但是自利的人有時卻不願意進行創新？」
- (4) 討論「外部性」的意義與類型。

五、(20%) 請儘量輔以圖表或方程式來說明需求函數與供給函數是如何導出來的。

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考試科目	微積分	所別	科管碩甲	考試時間	3月20日 上午第3節 星期日 (下)
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注意事項：1、請將算式以及推導過程臚列清楚。
2、每題 10 分，注意時間的分配。

- 一、某產品的總成本函數是 $y = f(x)$ ，
如果邊際成本函數是 $f'(x) = \frac{dy}{dx} = cx + bx^2 + ax^3$ ，固定成本是 F 。請問
平均成本函及數總成本函數分別為何？
- 二、已知 $z = x^2 + xy + y^2 - 3x + 2$ ，請求出 z 的最小值。
- 三、若 $x = \frac{1}{\sqrt{1+y^2}}$ ，求微分 $\frac{dx}{dy} = ?$
- 四、求函數： $y = \sin x$ 在 $x = [0, \frac{\pi}{2}]$ 間的平均值。
- 五、定義 彈性 $e = -\frac{dQ/Q}{dP/P}$ ，試求 $P = \frac{1}{\sqrt{Q}}$ 的彈性為何？
- 六、試求 $y \geq x^2$ 和 $y \leq 2 - x$ 所圍區域的面積。
- 七、已知 $\frac{dy}{dx} = x^2 y^3$ ，試求其一般解？
- 八、已知廠商生產的總成本是 $C = x^2 + 2y^2 - xy$ ， x, y 這兩種產品的總產量不能超過 8 個，試求最小總成本的生產法。
- 九、求積分 $\int \frac{x^3 + 6x^2 + 3x + 6}{x^3 + 2x^2} dx$ 。
- 十、何謂「微積分基本定理」？這定理的重要性何在？

考試科目	經濟學(甲)	所別	經濟學(乙)	考試時間	3月20日(上)午第 / 節 星期日
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一、市場中有 A、B 兩類消費者：

A 類消費者共有 100 位,每位 A 類消費者的個人需求曲線為： $q=5-2P$

B 類消費者共有 300 位,每位 B 類消費者的個人需求曲線為： $q=10-P$

其中 P 為價格，q 為個人消費數量。試求出市場之需求曲線？(10%)

二、完全競爭市場的結構能作最有效率的分配是基於哪些假設？(10%)

三、一群生產者（每人只生產一單位同質產品）的邊際成本曲線是 $MC=0.5Y$ ，而一群消費者（每人只消費一單位）的邊際價值曲線是 $MV=120-Y$ 。

請問：(40%)

- 1、如果生產者者組成聯盟，成為獨賣者；消費者毫無議價能力，請問獨賣者會如何取價，需求量是多少？
- 2、如果消費者組成聯盟，成為獨買者，而生產者毫無議價能力，請問獨買者會如何取價，需求量是多少？
- 3、如果生產者者組成聯盟，成為獨佔的供給者，而消費者也組成聯盟，成為獨買者；請問議價的空間何在？
- 4、呈上題，如果兩個聯盟無法直接接觸（分屬兩個遙遠的國家），必須透過一個貿易商來交易，而生產者及消費者都是價格的接受者。請問貿易商可以賺取多少利潤？交易量是多少？生產者及消費者分別接受什麼價格？
- 5、呈上題，如果生產者聯盟直接設立供銷處來進行貿易，請問生產者可以賺取多少利潤？交易量是多少？價格為何？

四、假設產業中的每一個廠商有相同的邊際成本曲線 $MC = c$ ，產業的需求曲線是 $P = a - NbQ$ 。請問在 Cournot 雙占 及合作雙占下，均衡的價格 P、產業產量 Q、各個廠商的產量及利潤 分別是多少？(20%)

五、請盡量輔以圖表或方程式來說明需求函數與供給函數是如何導出來的。(20%)

考試科目	企業管理個案	所別	科管所(學士後乙組)	試時間	3月20日 上午第3節 星期日
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個案一：Restructuring at Apple Computer (25分)

With its cash flow problems and loss of market share, will Apple Computer be able to survive this latest knockdown? Gilbert Amelio, the new CEO of Apple, believes these troubles are fixable and that this is an organizational problem of arranging resources to achieve goals. Some people believe, however, that Apple's problems will continue. Apple has been unable to market enough innovative and snazzy machines to justify higher prices and maintain a significant chunk of the personal computer (PC) market. Its global PC share dropped to 7.8 percent, down from 8.3 percent a year earlier.

Apple must develop a new strategy in which it should consider merging with a strong partner. Amelio's rescue plan includes the development of new products and eliminating the "dogs" within its product line. This would require intrapreneurship to create new products or ideas.

The issue of downsizing is prevalent because of Apple's streamlining of the Macintosh product line, and Apple's EWorld, its on-line service, may be axed. This may follow massive across-the-board layoffs.

Apple needs to restructure its organization. It will create new departments such as research and development and new job descriptions to meet the high technological demands of the computer industry. The R&D department will be a support function and advise the marketing department with regard to new products.

Questions

1. Explain how Apple's problems relate to its organization.
2. Define intrapreneurship and indicate what it means for Apple.
3. Should the research and development department be a line or staff function at Apple? Explain.

個案二：Marketing T-Shirts (25分)

Richard Schilo is the owner-operator of Richard's T-Shirts, a manufacturing business. The business has been in operation for two years. Richard has discovered through marketing research that teenagers desire his T-shirts. As a result of this research, Richard introduced a sports line of T-shirts with the endorsements of professional franchises. Richard has had tremendous success with this product line. His business has become highly profitable, having grown 100 percent from the first year's operation of \$150,000 in sales to a current level of \$300,000 in sales.

Additional marketing research has disclosed that the collegiate market offers growth-oriented potential. In the fall Richard plans to introduce a line of collegiate sweaters at a retail price of \$29.95. These sweaters will be sold in college bookstores around the country and will be priced competitively with other comparable sweater lines. The sweaters will be unique in their appearance, with embroidered college insignias in school colors and the school mascot on the sweater sleeve. The product will be packaged in a gym bag highlighting the athletic program of the student's choice. An exclusive brand name will be selected for each college and university. The plan is that the brand name will feature that school's athlete of the year.

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In the future Richard plans to introduce his product line to a nationwide network of retail establishments. His pricing strategy will continue during this expansion. His projections show that he will continue to build volume, especially in the retail discount sectors, where much growth has taken place in recent years.

Questions

1. Describe the target market for Richard's T-Shirts.
2. Identify and explain some common methods Richard is planning to use to differentiate his sweaters from other competing products.
3. What is the current phase of the product life cycle for these T-shirts?
4. Discuss the pricing strategy that Richard plans to use with the introduction of sweaters.

個案三：(25分)

1. 就最近所發生的聯電案，說明與企業管理有關的學理與議題。
2. 如果你(妳)是曹興誠，是不是可能會有什麼不一樣的作法？為什麼？

個案四：Apple 個案(25分)

隨著聖誕節腳步愈接近，蘋果電腦的聲勢愈來愈強，拜 iPod 數位音樂播放器大賣之賜，蘋果電腦成爲今年標準普爾指數表現第三佳的股票，一點都不輸能源股及原物料股。蘋果股價今年已大漲了 80% 以上，股價有可能挑戰 2000 年 9 月 28 日的 53.5 美元(10 月底蘋果股價在 45 元左右)，說明好的產品和泡沫無關，媒體也報導今年相關機構調查美國學生最想要的前五項聖誕節禮物中，iPod 名列其中。

今年等於是 iPod 年，數位音樂造就了蘋果史上成長最快速的產品，據報導光是第三季在美國就賣出了 86 萬台。兩年前在美國零售店的市占率是 33%，今年已達 82%。其中最大的意義，是讓蘋果不用只能依賴 PC。iPod 打造了一個和生活息息相關，而且簡單的商業營運模式：買了色彩造型更炫目的數位 iPod，再到 iTunes 去下載音樂。

這種「簡單關係」也讓競爭者緊追不捨，像新力、Dell 等都將推出類似產品，但大家還是看好 iPod，而 iPod 的成功也讓蘋果更加積極思考下一步，唯有造型又炫又簡單的產品才天下無敵。蘋果明年將推出的 iMacG5 系列，就是按此一原則，把主機完全隱藏到平面顯示器之後，讓外觀簡單到不行，只有輸入器和顯示器，卻表現個性及設計美感，蘋果正寄望 G5 能延續 iPod 的氣勢。

(選自數位時代，2004.11.1)

問題：

1. iPod 這樣的成功商品，何以出自 Apple 公司(而不是 Sony 或其他電腦廠商)？
2. 要成功開發出一個全新的商品，你(妳)覺得企業可能會碰到哪些挑戰？

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考試科目	管理個案	所別	科學碩士班組	考試時間	3月19日上午 星期六 09:00 午第一節
<p>一、1.技術密集產業中，開發專案的管理為何重要？ 10%</p> <p>2.開發專案的管理常發生那些錯誤？ 15%</p> <p>二、1.高階主管在開發策略中，所扮演的傳統角色為何？ 10%</p> <p>2. the development strategy leadership approach 產生的背景為何？提出者是誰？其主旨為何？能帶來什麼開發優勢 15%</p> <p>三、1.開發專案可以如何分類？ 15%</p> <p>2.這種分類管理上的用途為何？ 10%</p> <p>四、1.沒有任何公司擁有無限制的開發資源，公司如何管理有限的開發能量？ 15%</p> <p>2.說明 Exhibit 5 的意義，及管理上如何運用它？ 10%</p>					
<p>In technology-intensive environments, development projects are where the action is. They're where the "rubber meets the road." Through a combination of product and process enhancement activities development projects can provide a host of benefits for an organization. First, they can lead to market success in a rapidly changing, intensely competitive setting. New products and their associated manufacturing processes and delivery systems can leapfrog the competition, create strong barriers that</p>					
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others must hurdle just to stay in the game, and establish a leadership position as a dominant design. Furthermore, they can be the vehicle for entering new distribution channels and garnering new customers, and they can complement existing offerings by rounding out the line and targeting untapped niches.

Nearly as important as the promise of market success is the impact that effectively executed development projects can have on resource utilization: They not only capitalize on prior research efforts, but also leverage and enhance existing assets. What sales force or factory won't perform better with a new product that is hot in the marketplace than with an old, no longer distinctive product? Additionally, new products and new processes provide the means for an organization to overcome past weaknesses and establish an even stronger resource base for the future.

Still a third area of promise associated with the commercialization of new products and processes is that of organizational renewal and change. Organizations consist of people, and people become

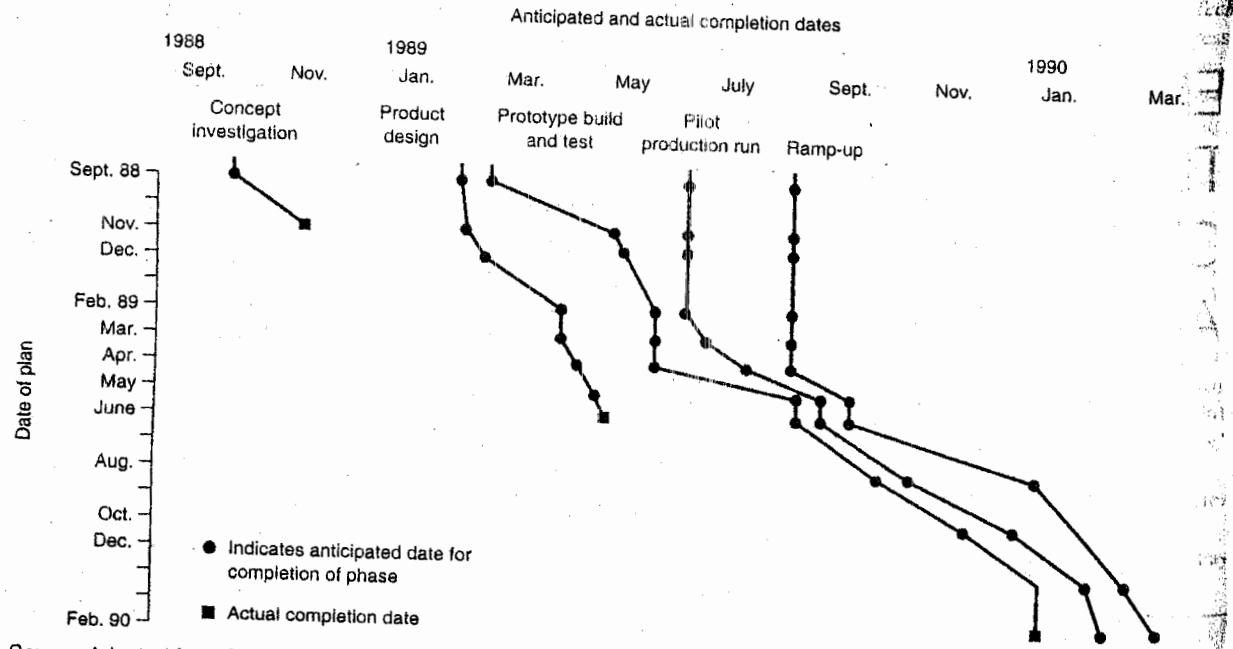
excited when they see growth opportunities being captured by new products and processes. Furthermore, the adoption and implementation of new technologies that transform aging assets can enable a business to recruit, train, and develop better people than its competitors. Being part of the team that succeeds in achieving its development goals is rewarding and fulfilling.

Unfortunately, far too often the reality surrounding many development projects is that although they begin with great expectations on the part of all involved, they fall far short in the end. See Exhibit 1 as an example. Even projects with milestone dates, resource plans, and aggressive market goals often slip as they encounter unexpected problems and organizational miscues, arriving late and no longer on target for the marketplace.

Why is it that so many development projects fail to deliver fully on their planned goals and anticipated benefits? Why do firms—even those that explicitly recognize the importance of product development—find it so challenging to focus resources

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EXHIBIT 1 The Reality of Many Development Projects: Schedule Slippage in the A14 Stereo Project

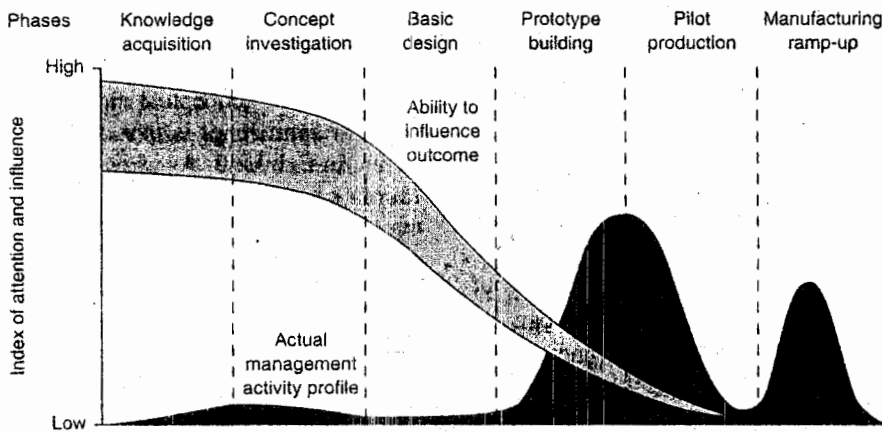


Source: Adapted from S. C. Wheelwright and K. B. Clark, *Revolutionizing Product Development* (New York: Free Press, 1992), p. 11.

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EXHIBIT 2 Timing and Impact of Management Attention and Influence



Source: R. H. Hayes, S. C. Wheelwright, and K. B. Clark, *Dynamic Manufacturing* (New York: Free Press, 1988), p. 279. See also F. Gluck and R. Foster, "Managing Technological Change: A Box of Cigars for Brad," *Harvard Business Review*, September-October 1975, p. 141.

and execute projects as intended? Additionally, why don't the increased dosages of management attention that inevitably result when major projects slip seem to have any impact on project effectiveness?

The perspective of this discussion is that an organization can achieve robust and predictable development capabilities that will achieve their intended goals in the marketplace, within the organization, and for the individuals involved. However, doing so requires a host of skills, tools, and concepts that in many instances differ significantly from the natural inclinations common in organizations. At the core of this need for change is management itself. In too many instances, management at all levels fails to provide the leadership required for success. The heart of the problem is management, but management is also the solution.

The magnitude of the change required on management's part is captured clearly by Exhibit 2. As illustrated, most senior managers play little, if any, role in the early stages (knowledge acquisition, concept investigation, and basic design) of a development effort. Once a project progresses to the point of building prototypes and trying to demonstrate the performance characteristics (or lack thereof) of those prototypes, management comes to life and remains attentive until prototyping problems have

been resolved. When the product is introduced, all too often customers discover a number of remaining issues and problems, and management again focuses its attention on the effort.

The problem with such a pattern is that management is only reactive. As suggested by the shaded curves in Exhibit 2, the greatest amount of management's energy on the project is expended when the ability to influence its outcome is at a minimum. It would be far more effective to focus management attention and effort on development activity at the front end or even the preproject phase of development. To do so, however, management must have the appropriate skills, tools, and methods to provide the foundation for a different type of involvement in development. Once accomplished, management can then spend a far greater portion of its energies assessing the lessons learned from individual projects, using them to improve development capability on an ongoing basis, and laying the groundwork for subsequent projects.

The remainder of this discussion is organized around three areas of management activity: preproject or front-end planning, project execution, and postproject learning. This combined set of management activities is what constitutes the development strategy for a business. The concepts, frameworks,

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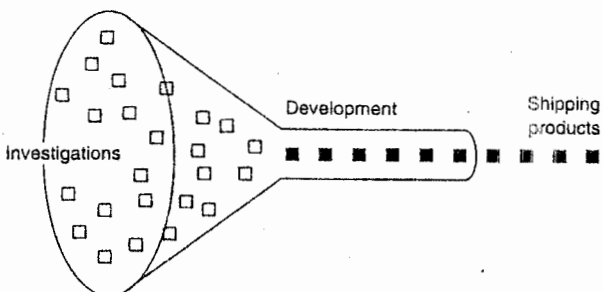
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and tools that have been found particularly effective in each of these areas will be described, and the subsequent readings and case studies will elaborate on those and illustrate their use in practice. This discussion begins by providing an overview of development strategy and a detailed examination of the pre-project stages, including a descriptive framework for categorizing individual development projects into different types. Next, four alternative team structures for organizing the resources used to carry out a development effort are outlined. These can be used effectively to match individual project needs and requirements with the organization's resources and business objectives. The final portion of this discussion focuses on specific ways an organization can learn across a series of development efforts and apply that learning to achieve continual improvement in development speed, productivity, and quality. In addition, an expanded role for management in achieving longer-term development goals is outlined.

DEVELOPMENT STRATEGY AND PREPROJECT MANAGEMENT

While individual development projects are where much of the action is, senior management can have its greatest leverage in the preproject stages. There are two quite different views, however, as to the nature of senior management's role in these preproject activities. Both appear to be based on a similar overall concept of how development activity can be planned and managed, but the specific senior management activities under each approach

EXHIBIT 3 The Development Funnel



Source: Adapted from R. H. Hayes, S. C. Wheelwright, and K. B. Clark, *Dynamic Manufacturing* (New York: Free Press, 1988), p. 295.

are radically different, as are the results. We'll refer to the more frequently encountered approach as the *traditional senior management approach* and the alternative as the *development strategy leadership approach*.

The overall conceptual view of development activity for both approaches is that of the development funnel, shown in Exhibit 3. As suggested in this figure, organizations encounter a range of product ideas and concepts that can be investigated as potential new products and processes. From that range of possibilities, the organization must pick a handful of specific projects to which resources will be applied, with the goal of creating on-target, on-time, on-budget products and processes that can be introduced to the marketplace in an effective and efficient manner.

The *traditional role* of senior management in the development funnel is to select, consider (screen), and evaluate a handful of project ideas from all of those available, and then make "go/no-go" decisions with regard to those projects. Senior management thus reacts to the possibilities raised from throughout the organization (and perhaps adds a few ideas of its own) and commits resources to get selected projects developed and into the marketplace. Unfortunately, this traditional view has several shortcomings and weaknesses.

First, it assumes that the set of concepts proposed by the organization adequately covers the firm's opportunities and needs for new products and processes. Second, it assumes that senior management will have the required information to decide properly which product ideas to develop, in the context of ongoing business and product line strategies. Third, this view presumes that advanced development and technology work will have occurred before each development project receives its initial funding and approval. Finally, it assumes that senior management will adequately consider the capacity and resources requirements for prospective individual projects and for the mix of projects already approved. Unfortunately, few of these assumptions hold in practice, and the traditional approach ends up, again, being reactive, piecemeal, and tactical rather than proactive, comprehensive, and strategic.

A much more effective way to achieve the full potential of senior management involvement in development activity is the *development strategy leadership approach*. While based fundamentally on the idea of the development funnel, it creates a far more proactive role for senior management and incorporates a number of tools and techniques that facilitate senior management effec-

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tiveness. First, it seeks to put senior management in the position of motivating, guiding, and leading the organization to create the best set of projects. This includes articulating a set of criteria for what would constitute the "correct set" of development projects and connecting the process by which those criteria are applied with product, market, and technology strategies. Senior management thus helps to ensure that selected projects make the best use of existing resources, fit with ongoing business strategies, and are likely to achieve the firm's development objectives. Development projects are the means by which a firm enhances its capabilities; the aggregate set of approved projects is the basis for creating the development capabilities the firm needs and desires in the future.

A second way in which this approach creates substantial leverage is by placing senior management in the position of setting guidelines, general boundaries, and charters for individual projects so that those assigned to carry out such projects can focus their energies in the ways most likely to fulfill senior management's expectations. Thus, this approach avoids having senior management involved in too much of the detailed specification-setting refinements and instead emphasizes broad boundaries that differentiate projects and set clear objectives for what each project is to accomplish.

Third, after creating an appropriate set of projects and defining the boundaries and charters for each project within that set, senior management is in a much better position to make resource allocation and timing decisions that recognize available development capacity and the need to avoid overcommitting scarce resources. It is easier to track a handful of on-target projects than to jump from one project to another as the organization gradually recognizes that its development resources are overcommitted by a factor of two or three. Having contracted with individual development teams as to the charter and bounds of each project, senior management can focus its attention on providing tools and support so that all approved projects move ahead on schedule, rather than constantly reallocating resources in response to current crises and delays.

The results of such a development strategy leadership approach have been described by Clark and Fujimoto in their study of the worldwide automotive industry.¹ These authors looked at major new car development programs

¹K. B. Clark and T. Fujimoto, *Product Development Performance* (Boston: Harvard Business School Press, 1991).

in European, American, and Japanese auto companies and measured results in terms of project cycle time, resource requirements, and product quality. Their findings confirm that automotive companies that use the traditional approach take 20–25 percent longer, require almost twice as many engineering hours, and tend to have significantly lower product quality than do firms at which senior management follows the development strategy leadership approach. Clark and Fujimoto also discovered that the benefits of the latter approach were becoming sufficiently clear that the major auto companies following the traditional approach were focusing significant energy and resources on developing the ability to pursue the development strategy leadership approach.

To understand what is required of senior management to carry out this new approach effectively, it is helpful to examine its three distinctive activities. The following subsections discuss how senior management can create the right set of projects, charter and bound individual projects within that aggregate set, and then balance the supply and demand of resources to best achieve the firm's development objectives.

Creating the Aggregate Set of Projects

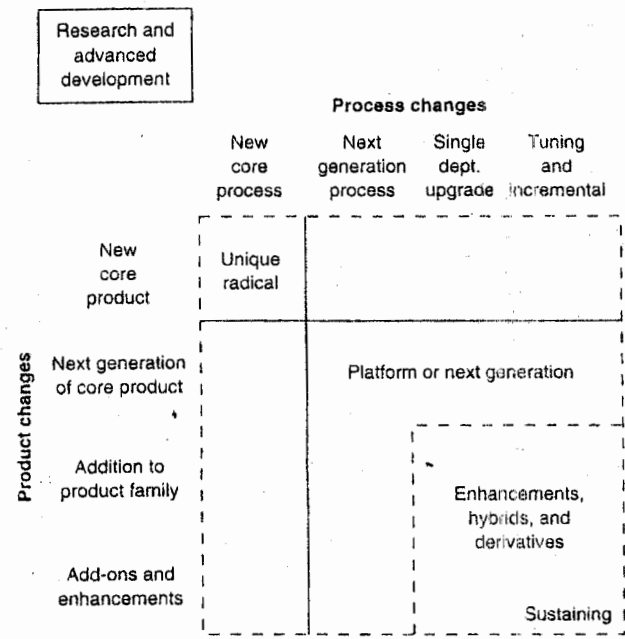
For an organization to get the most out of its development resources, it is essential that the right mix of projects—those that use available resources to support existing market segments and to open up new market segments while appropriately utilizing new technologies—get created and proposed to the organization. In terms of the funnel in Exhibit 3, this process can be compared to widening the mouth of the funnel so that a complete range of alternatives is investigated before specific choices are made. This task, however, goes beyond simply encouraging the generation of more ideas; it involves combining and bundling ideas that will allow the organization to cover most effectively the needed areas of new product and process development. Thus, it is essentially a matter of creating and defining the alternatives that the firm can pursue, not simply investigating and screening those that naturally arise.

One way to characterize and organize this task is by using a two-dimensional diagram (see Exhibit 4) that defines individual projects according to the degree of change in the product and manufacturing process they entail. The greater the degree of change along either dimension, the more resources that are likely to be needed in completing that project.

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EXHIBIT 4 Creating the Mix of Product/Process Development Projects



Source: Adapted from S. C. Wheelwright and K. B. Clark, *Revolutionizing Product Development* (New York: Free Press, 1992), p. 93.

The two-dimensional construct of Exhibit 4 (called the *aggregate project matrix*) classifies individual projects into five types. The three central types—derivative/enhancement/hybrid, platform/next generation, and unique/radical—are known as *commercial development projects*. They lead to new products and processes, providing the benefits typically sought through the application of development resources. The fourth category—sustaining—often uses similar development resources as commercial development projects, but it does not create new products or processes. Rather, sustaining projects maintain or support existing products and processes or tailor them for a single customer. When new commercial development efforts are introduced to the marketplace before they are fully ready, the sustaining effort needed to make engineering change orders and other modifications so that products will perform up to customer expectations can be substantial. One reason for explicitly identifying such sustaining projects is to recognize the resource needs of those projects and the fact that they can often divert attention from the more traditional, more visible, and higher leverage development efforts.

The fifth category—research and advanced development—is generally the technical precursor to a commercial development effort. These projects prove the feasibility of a given product or process concept and validate the existence of the technical knowledge and invention required to make the concept a commercial success. Because invention and technical exploration so often yield unpredictable outcomes, research and advanced development usually precede a commercial development project to ensure that development activities will have a very high probability of technical and market success.

Some companies that have used this aggregate project matrix tool have opted to plot "technology risk" on the vertical axis—ranging from little technological uncertainty at the bottom to substantial uncertainty at the top end. They assess the technical risk entailed in both product and process projects on this single dimension. This allows them to measure the intended market impact of the project on the horizontal axis. Projects positioned at the right side of the matrix are replacement products, targeting existing customers in existing markets. Projects in the middle aim to strengthen the company's market share in existing markets that it does not currently serve well. Projects that are positioned at the left end of this continuum are charged with creating new markets. Whether executives use technology-market axes or product-process axes, the characterization of project types noted in Exhibit 4 still applies.

For any ongoing business, a mix of all five types of projects is essential to long-term success. While the majority tend to be created, defined, and resourced within the organization, it is possible for some portion to be subcontracted or partnered with other organizations. For instance, it is not unusual for a business to develop relationships with an industry association group or a university, with the intent of having that group be the source of much of the research and advanced development effort needed by the business. Similarly, firms will often acquire another business to gain ownership of a unique/radical new product or process, or will subcontract to a service organization or field support group part of the sustaining effort needed for the existing product line. It is less common that firms will subcontract or partner platform/next-generation efforts unless these happen to be the first such efforts or represent a diversification move. The key point is that one of senior management's roles is to recognize explicitly the needs of its business for an appropriate mix of these projects and then to determine the most effective way to get those projects com-

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pleted—whether in-house, through acquisitions, with a partner, or with a subcontractor.

The proportion of effort needed in each of these five areas depends in part on the firm's strategy, but also on the technical opportunities available and the maturity of the firm's product lines. For instance, a large firm that dominates many of its markets, tends to have a broad product line, and may contemplate only incremental changes in its basic technology (such as Kodak in its film business) is likely to support a few selected research and advanced development projects and an occasional platform/next-generation effort (such as developing a whole new line of film), but it will focus most of its development resources on enhancement/derivative/hybrid projects or on sustaining and supporting its existing product lines. In the biotech industry, on the other hand, a firm might spend the vast majority of its development resources on research and advanced development, unique/radical projects, and an occasional wholly new platform. Such a firm would view itself as part of a young, emerging industry in which the leverage is in establishing strong positions in whole new areas with radical new products.

As a general rule, a company that is seeking to accelerate its growth rate would focus a larger proportion of its development resources on platform and breakthrough projects. A company whose strategic mandate was to wring maximum profit from its investments in R&D would likely focus most of its resources at derivative and sustaining projects.

There is no single best mix of projects for every company or even for all the companies in a single industry. What is important is for senior management to understand where the opportunities exist, where the payback will be greatest, and what mix and proportion of different types of projects will best enable the firm to accomplish its business strategy.

Chartering and Bounding Individual Projects

After deciding on the mix and proportion of project types, senior management needs to help create expectations as to what individual projects are intended to accomplish, where they fit in the overall set of projects, and what resources will be made available to the team executing each project. Here again, using the five types of projects is one way for management to establish and bound individual project expectations and temper and balance project objectives and resources. For instance, *derivative projects* can range from cost-reduced versions

of existing products to add-ons or enhancements for an existing production process. Development work on a derivative project typically will take less time and fewer resources and be constrained in its performance achievements by the existing platform product or process from which it is derived. They typically target markets and customers that exist and are well understood. Thus, these projects typically require less creativity and are more predictable in their outcomes.

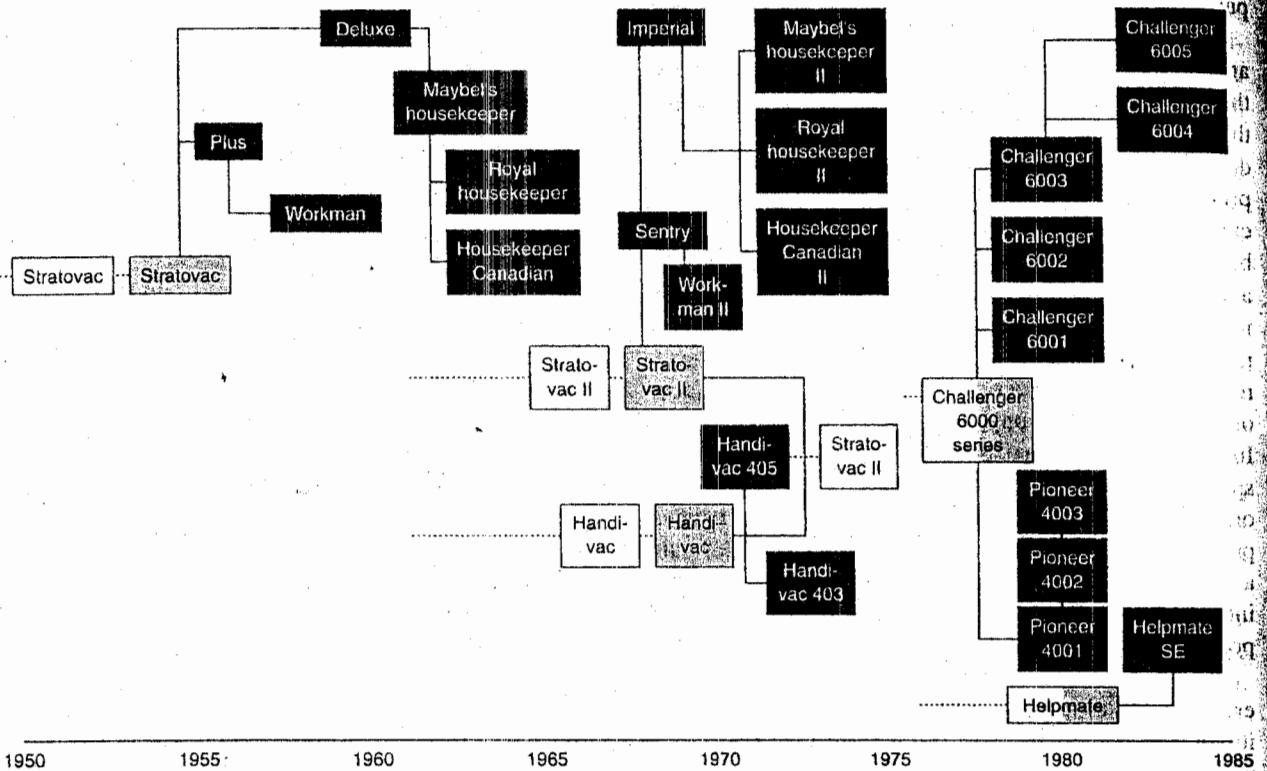
Breakthrough projects, on the other hand, involve significant changes to existing products and processes and require much more creativity, greater degrees of freedom, and more time and resources. Like the initial efforts to develop the compact disc or fiber optics, they create whole new product and process categories that can define a new market. Their results and requirements are much less certain than those of derivative projects and typically require a more experienced and aggressive effort. They tend to be high risk and high return, both to the organization and to those who work on them.

Because breakthrough products often incorporate revolutionary new technologies or materials, they may require dramatic changes in manufacturing processes. This requires that the development team be given considerable latitude in designing both the product and the process. Often this includes providing access to a variety of advanced development projects and their results so that multiple new technologies can be called upon to achieve the dramatic results expected.

Platform projects, which fall in the middle of the commercial development spectrum, are considerably harder to define and bound because they need to be compatible with existing products and processes and yet be sufficiently new and bold that they can serve as a basis for subsequent derivatives, enhancements, and other variations of a basic product/process. For instance, Honda's 1990 Accord line is a new platform that replaced its 1986 platform. Honda introduced a number of significant changes in both product and process but no fundamentally new technologies. Similarly, in the early 1990s, Kodak's single-use camera—available in several different versions—was built off a single platform, while the over 200 versions of Sony's Walkman were derived from one of three platforms, each of which was overhauled and redesigned (i.e., a new generation was created) every two or three years. The extendability of a platform—the range of derivative products that can be built with small incremental investment using the core platform design—is in fact a key metric of how good a platform design is.

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EXHIBIT 5 Creating Product Families Via Development Projects



Source: S. C. Wheelwright and W. E. Sasser Jr., "The New Product Development Map," *Harvard Business Review*, May-June 1989, pp. 112-25.

How individual projects are chartered and bounded is important in giving focus and purpose to the development team charged with completing each project. The resulting product line, its basic architecture, its product families, and its range of variations will be the consequence of the set of breakthrough, platform, and derivative projects pursued in development. Organizations have discovered tremendous advantage in differentiating types of development projects such that they can leverage scarce development resources, address markets appropriately, and provide distinctive products offering competitive advantage. Chartering and bounding individual projects is a critical step contributing to the organization's success in achieving these goals. An example of how this might play out over time is shown in Exhibit 5 for a fictitious vacuum cleaner company. The exhibit outlines three generations of product, each involving one or more new platforms and a number of carefully selected and positioned derivative projects aimed at different segments and distribution channels. Senior management can play a

pivotal role in creating and guiding product and process generations and architectures.

Developing and Applying Resources to Selected Development Projects

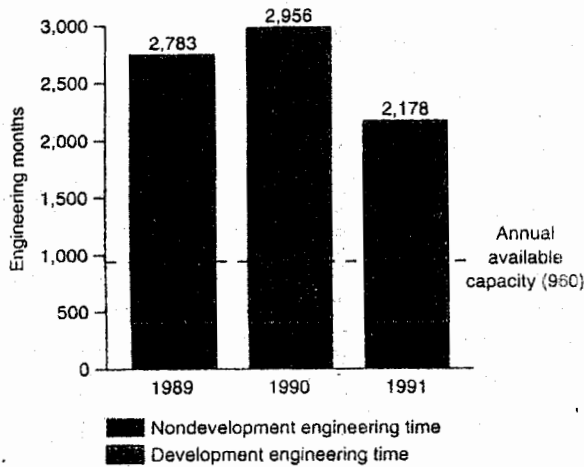
It is perhaps easiest to understand senior management's role in providing and allocating resources by identifying the two most common problems firms have in this area: undertaking many more projects than can possibly be completed with the available resources and assigning critical resources to work on several projects concurrently. Both problems reflect a lack of discipline and management's unwillingness to make hard choices. Generally, the impact of these problems is far more detrimental and pervasive than most organizations recognize. A simple example can help to illustrate the consequences.

Suppose a firm has a total of 80 full-time development and design people available to work on commercial development projects (derivative, platform, and breakthrough). This means that a total of 960 people-months

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EXHIBIT 6 Typical Development Capacity Predicament



Source: S. C. Wheelwright and K. B. Clark, "Creating Project Plans to Focus Product Development," *Harvard Business Review*, March-April 1992.

can be allocated each year to these three types of development projects. Experience in industries as diverse as computers, scientific instruments, medical devices, and pharmaceuticals suggests that resources are typically overcommitted to the extent shown in Exhibit 6. As suggested, the representative firm with 80 full-time employees engaged in development activity might find that over one-third of the time actually available is spent on non-development engineering tasks (such as sustaining engineering or other special requests the organization might place on these resources). Even more importantly, however, if one were to take all the projects currently considered active and estimate the amount of resources (in development people-months) required for completion and consider their desired completion dates, one would find that the firm had overcommitted its available development capacity by a factor of two or three. That is, the vast majority of firms have many more projects under way than they have resources to staff and complete the projects by the desired introduction dates. This puts development activity in a catch-22 mode: Priorities continually shift and people are moved from one project to another as the organization robs Peter to pay Paul in hopes of completing projects as scheduled. Of course, everybody knows that project commitments far exceed resources, making a game out of who will get priority and what projects will slip.

In addition, because there are not sufficient resources for all projects, the tendency is to commit particularly

critical resources to as many as six or eight concurrent projects. Unfortunately, recent studies suggest that overcommitting individual resources actually reduces their effective capacity. That is, overcommitted individuals end up spending additional time going to meetings, getting back up to speed, correcting trivial errors, and so forth, thereby reducing their effective development capacity when it is most needed. This further exacerbates the overcommitment problem, leading inevitably to frustration, disappointment, and burnout.

In fact, the concept that an engineer, scientist, or marketing person is assigned to work simultaneously on multiple projects is quite misleading. In reality, at any point in time each person can work on only one project. The others sit, waiting to be worked on. If the people in a development organization are, on average, assigned to four projects each, an average of only one project is getting worked on. The other three projects are sitting in the intellectual equivalent of work-in-process inventory (WIP). This has the same impact on the speed and quality of development that WIP has on a manufacturing organization.

When we observe a small, seemingly faster company beat a larger, more ponderous competitor to market, it often is the simple result of the small company's engineers having only one project to focus upon—they have no WIP to slow them down. When larger firms allow their product line breadth to reflect itself in multiple project assignments per engineer, it slows the company down. The root cause of the difference is not company size per se. It is the number of projects in WIP.

Senior management must have the discipline to decide which projects are most important, to charter and bound those projects appropriately, and to commit to projects only up to the point at which capacity will allow completion of all the resourced projects. For most organizations, this means cutting the current number of projects by one-half to two-thirds—a difficult pill to swallow. It always seems easier to pretend that all projects underway could be completed if everyone worked harder and longer. Experience suggests that this is a fiction and that the best way to complete more projects on time, on budget, and on target is to do fewer projects and to assign scarce resources to, at most, one major and one minor project. However, when an organization has historically done the opposite, it requires senior management commitment and leadership to make this new set of principles a reality and to impose the discipline needed to avoid the all-too-common overcommitment. As chaos is reduced and focus on development resources increases, it

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is much easier for senior management to identify the additional resources and capabilities that are required and justified and to make appropriate changes. This puts senior management in a proactive role, helping to build the organization's development capabilities, rather than leaving it in a reactive role that inevitably dissipates much of the development activities' potential effectiveness.

In summary, senior management can have its greatest impact, either positive or negative, during the preproject phase. By shifting to a proactive mode and adhering to a handful of principles and guidelines, senior management can help the entire organization leverage its existing capabilities and enhance its future capabilities. Much of this can be done around the aggregate project plan framework of Exhibit 4 and the repeated application of the following eight-step procedure:

1. Define the primary types of commercial development, advanced development, and sustaining activity projects.
2. Determine the FTEs (full-time equivalents) and cycle time requirements for representative projects of each of those types.
3. Identify existing resources and compare those with the capacity required to complete existing projects on time.
4. Compute the implied capacity utilization from Step 3 and make the adjustments to bring supply and demand into balance.
5. Determine the mix of project types required in the future to achieve the firm's business objectives.
6. Estimate the number of projects of each type that can be undertaken to provide the desired mix and yet not overcommit existing development resources.
7. Create and define the set of specific projects that will be underway at various points of time in the future.
8. Work to increase the productivity of the development resources, thereby enhancing development capacity and capability in future time periods.

The case studies about Kirkham Instruments and Medtronic in this section describe two companies' attempts to use the aggregate project planning tool to manage new product development more effectively. Kirkham stumbled badly, while Medtronic boosted its fortunes dramatically by using this method.

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