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Utilizing Innovation and Strategic Research and Development to Catalyze Efficient and Effective New Product Development

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1. Introduction

The ability to effectively innovate and develop new products is a vital core competency that any company must possess if it is going to be profitable and experience growth. At the same time, the innovation and effective new product development process is one of the most challenging to nurture and shepherd through to successful completion. It involves a combination of high risk and high return; mission critical importance; and immense scientific, engineering, and financial hurdles. But ultimately, the greatest paradox that surrounds successful new product development is the need for free, unfettered creativity to complement tremendous systematic discipline.

There appear to be three key components to successful strategic innovation and research and development. First, strategic innovation and new product development rest on the effective and efficient use of resources to create clearly differentiated products that customers perceive as more valuable. Second, the process demands a seamless integration and alignment of research and development and new product development objectives and goals throughout the relevant departments of an organization. Third, research and development and new product development efforts should be strategic in nature. This suggests the development of new research and development capabilities, new relationships with customers or suppliers, and more efficient and effective deployment of resources that create lasting competitive advantage for the company.

This chapter will illustrate the importance and interconnection of strategic innovation, research and development, and new product development efforts with clear operations strategy. It will also highlight some of the latest concepts, tools, and strategies in research and development and new product development, displaying why it is vital for firms to establish effective product development processes. Furthermore, it will show how developing this internal capability will permit a company's long term survival and growth in a highly competitive global marketplace.

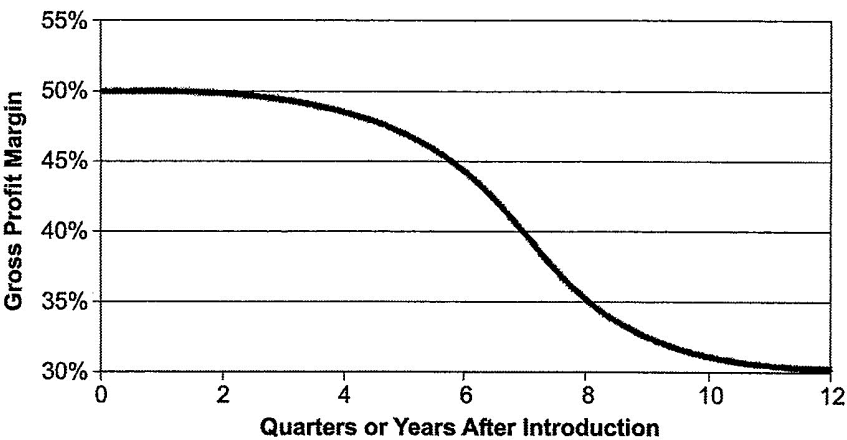
2. Why is new product development important?

Even though new products require substantial resources, involve high levels of risk, and often result in failure, in many industries, the development and introduction of new

products can lead an otherwise faltering company to success. Firms undertake systematic new product development efforts in order to gain competitive advantage, increase market share, reach higher levels of profitability, improve brand equity, and develop new research and development capabilities.

3. Sources of competitive advantage

Firms innovate and develop because new products provide unique opportunities for competitive advantage. Early movers have the advantage of taking a leading role in setting industry standards for emerging product categories. Pharmaceutical companies, for instance, often undertake the simultaneous development of multiple new products because their existing drugs no longer enjoy patent protection. Furthermore, in today’s business environment, the products and services produced by a company serve as its face to the public. That is, customers judge a company on its output: great products and services equal a great company. As a result, companies choose to invest significant amounts of time and financial resources in developing new products and services. The innovative product line of Apple, including both the iPhone and iPod, can be seen as instrumental in the survival and emergence of a stronger and more competitive corporation. On the other hand, as the photography industry shifted to a digital focus, Eastman Kodak failed to move forward in creating innovative product offerings. The downfall of the corporation is largely attributed to that decision. As these examples demonstrate, a strong connection exists between how companies go about developing products and services in the marketplace, and the ultimate success or failure of those companies. Accordingly, many seek to understand the evolution of such offerings and learn how to develop innovative products in an efficient and cost effective manner.



Note: Gross Profit Margin drops over time as commoditization drives prices down

Fig. 1. Cumulative advantage of early entrants (Holtzman, 2010).

4. Market share gain

Over the past several years, two factors have changed the process of gaining market share: an increase in the speed and scale of market and technological changes, and a greater understanding of the interconnectivity of the processes by which products and services are developed and the resulting outcomes of those processes. These factors bring additional

focus on the need to be first to market. New products introduced in the marketplace provide additional opportunity for the company to gain first mover advantage. For example, Toyota introduced a hybrid car, the Prius, in advance of its competitors. This has afforded Toyota a dominant position in the fuel-efficient and environmentally friendly automobile market. By developing new products, a company can capture a significant share of the market before competitive products are introduced.

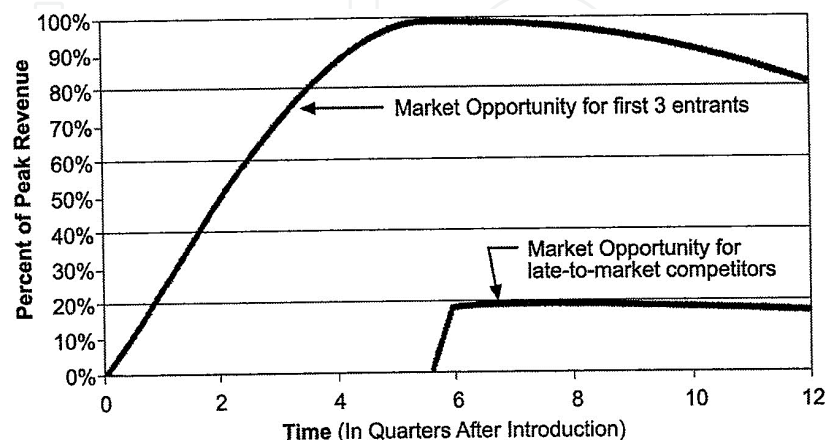
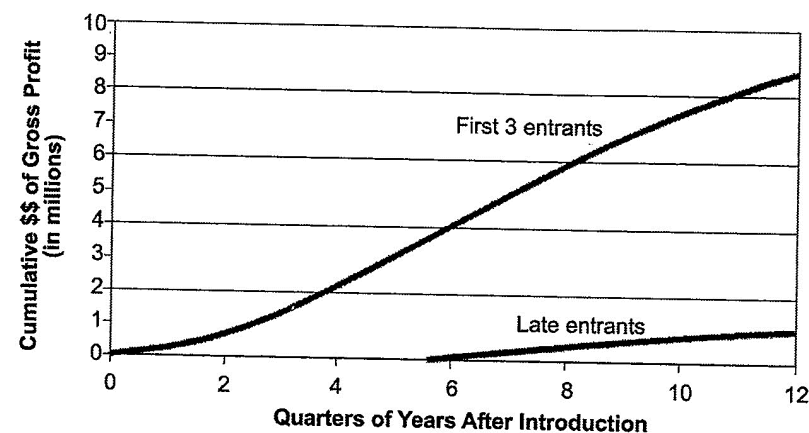


Fig. 2. Gross profit margin over time (Holtzman, 2010).



Note: The problem with not being among the first to market with an innovation is clear: late entrants frequently do not earn enough to repay their investment in development, and may be in a significantly weakened condition, unable to fight the next battle

Fig. 3. Early entrant advantage (Holtzman, 2010).

5. Higher profitability

During the early stage, a new product faces less competition than a product in a mature market; therefore, its profitability tends to be higher. This higher profitability, in part, is due to the company capturing a larger share of the market than it would be able to obtain were competition present, as outlined above. It can also partially be attributed to the buying habits of consumers. When a new product is introduced, it will appeal to the innovative crowd. This is particularly true in regard to technological products. From there, if successful, it will eventually reach the main stream, but its popularity, as well as its profit margins, will decrease as new products continue to be introduced and the market becomes saturated with

competitive products. This general trend is observed in many industries, and some industries, like the pharmaceutical industry, lock out the competition for several years through patent protection. Patent protection is highly beneficial to pharmaceutical companies because of the extremely high costs and low success rates associated with new product development in that industry.

6. Brand equity

The development of innovative and creative new products is a powerful source of customer loyalty and positive corporate image. Though it remains extremely difficult to quantify the monetary value or goodwill associated with brand image, the imperative nature of strategic actions with this focus is seen in the success that companies like Apple, Google, and BMW have achieved through the results of new product development efforts. While new product development is not the only factor contributing to the image of a company, it is reasonable to assume that substantial brand equity is obtained in this manner. When measured through the use of marketing tools, results show that firms with more successful new product development command higher respect from customers, which leads to enhanced long-term profitability.

7. Resource allocation and development of future research and development

A firm's competitive advantage evolves from its available resources. Resources are physical assets, such as land, equipment, buildings, and cash; intangible resources, such as brand name, market share, product patents, and technological know-how; or capabilities, such as learning proficiencies, product development processes, fast delivery times, and managerial abilities. Analyzing a firm's resources is an important step for a manager to take when formulating and implementing strategy. Valuable resources must support a successful strategy, and when a strategy changes, accompanying adjustments in competitive advantage must be made, which, in turn, will require further resources.

Very often, sustainable sources of competitive advantage evolve into core competencies in a company. Core competencies are capabilities that emerge over time as being central to a firm's overall strategy and upon which the firm's strategy is eventually based. For example, Intel's core competency is the ability to produce the fastest chip in the world. Intel has built its strategy around this core competency for the past decade. More recently, it has begun to stress efficiency in manufacturing because it realizes this will become a more important strategic factor as the industry matures. Shifting its focus will enable Intel to develop new capabilities and competencies that will enable it to continue to compete strategically as a market leader despite changes in the market itself. Multi-business firms build their businesses around a core competency, and this enables them to effectively and efficiently execute a cohesive strategy in all of their businesses.

One of the key strategic decision-making judgments managers face is deciding which resources to develop or acquire. Senior management spends an inordinate amount of time analyzing, selecting, acquiring, and developing the resources necessary in enabling its firm to be competitive. These resources and competencies must be constantly upgraded or altered to enable a firm to maintain its competitive advantage relative to other firms in the market.

8. A mathematical view of the resources allocation problem

Mathematical tools can be used to provide guidance in the deployment of resources in research and development efforts. These tools are only mentioned here in brief, as a detailed discussion is beyond the scope of this text. Linear programming is a widely used mathematical technique designed to help research and development managers plan the optimal allocation of resources.

Requirements of a Linear Programming Problem:

All linear programming problems seek to maximize or minimize some quantity (number of new products brought to market or number of new innovative products or processes). This property is referred to as the **objective function** of a linear programming problem. The major objective of a typical firm is to maximize dollar profits in the long run. In the case of a high technology company, it could be tasked with maximizing the most new innovative products to market in a 6 or 12 month period of time. The presence of restrictions, or **constraints**, limits the degree to which a company can pursue its objective. Therefore, it wants to maximize or minimize a quantity (the objective function) subject to limited resources (the constraints). In order for these calculations to be useful, the company must be deciding among alternative courses of action. For example, if a company can take on three major research and development projects, senior management may use linear programming to decide how to allocate its limited resources (engineers, scientists, lab equipment) among these projects. If there are no alternatives to select among, linear programming is unnecessary. The objective function and constraints in linear programming must be expressed in terms of linear equations or inequalities.

Formulating the Linear Programming Problem:

One of the most common linear programming applications is the product-mix problem. New product development or research and development efforts generally undertake multiple initiatives. Two or more research and development efforts are usually pursued using limited resources. The company would like to determine how many units of research and development products or new products it should produce to maximize overall profit given its limited resources. Note: the reader should not assume that the solution to the linear programming problem is the only variable that needs to be taken into consideration when we discuss research and development efforts. Since new product development and research and development differ from a traditional manufacturing problem, non-quantitative considerations such as strategy and innovation and research and development capability, as well as the “disruptiveness” of the innovation, need to be given careful consideration. The linear programming exercise does provide valuable guidance as to what research and development projects (or activities) potentially have the highest value. The example below is helpful in illustrating some of the basic mathematics in solving a linear programming problem.

The ABC High Technology Company:

The ABC High Technology Company currently has two major research and development projects: (1) the pink R-Bot, a new medical imaging device, and 2) the Chemical BlueBerry, a device capable of detecting noxious chemicals in liquid, gas, or solids with incredible accuracy and needing only tiny samples. The research and development effort

for each product is similar in that both require a certain number of hours of electronics engineering and a certain number of hours of chemical engineering. Each pink R-Bot takes 4 hours of electronics engineering and 2 hours of chemical engineering work. Each Chemical Blueberry requires 3 hours of electronics engineering and 1 hour of chemical engineering development efforts. During the current research and development efforts, 240 hours of electronics engineering time are available, and 100 hours of chemical engineering time are available. Each pink R-Bot sold (if successfully produced) yields a profit of \$7; each Chemical BlueBerry produced (if successful) may be sold for a profit of \$5.

ABC’s challenge is to determine the optimal combination of pink R-Bot’s and Chemical BlueBerrys to maximize profit. Assume for this example that both new products share the same viability and market success. This new product and research and development mix of resources situation can be formulated as a linear programming problem.

The table below summarizes the information to formulate and solve this problem (see Table Ex. 1). Furthermore, let’s introduce some simple notation for use in the objective function and constraints.

Let:

- X_1 = the number of pink R-Bots to be developed
- X_2 = the number of Chemical BlueBerries to be developed

Engineering Department	Pink R-Bot	Chemical BlueBerry	Available Hours/Week
Electronics	4	3	240
Chemical	2	1	100
Profit per Unit	\$7	\$5	

Table 1. Hours required to Develop One Unit of New Research & Development Effort.

Now we can create the LP objective function in terms of X_1 and X_2 :

Maximize Profit = $\$7X_1 + \$5X_2$

Our next step is to develop mathematical relationships to describe the two constraints in this problem. One general relationship is that the amount of a resource used is to be less than or equal to ($\leq$) the amount of resource available.

First constraint:

Electrical engineering time required is $\leq$ Electrical engineering time available.

$4X_1 + 3X_2 \leq 240$ (Electrical Engineering time available)

Second constraint:

Chemical engineering time required is $\leq$ Chemical engineering time available.

$2X_1 + 1X_2 \leq 100$ (Chemical Engineering time available)

Both of these constraints represent possible research and development resource capacity restrictions and certainly will affect the total profit outcome. For example, ABC Technology

Company cannot develop 100 pink R-Bots because if $X_1 = 100$, both constraints would be violated. ABC could also not allocate its resources such that $X_1 = 50$ and $X_2 = 10$. This constraint illustrates that interactions exist between variables. The more units of one new product that are worked on, the fewer resources ABC Technology has to allocate to the other research and development efforts.

The easiest method to solve a small LP problem such as that of ABC Technology Company is the graphical solution approach. The graphical procedure can be used only when there are two decision variables such as in our example. When there are more than two variables, it is not possible to plot the solution on a two dimensional graph; we must then turn to more complex approaches (see other books on Management Science or Operations Research).

Graphical Representation of Constraints:

To determine the optimal solution to a linear programming problem, we must first identify a set, or region, of feasible solutions. This is solved by plotting the problem’s constraints on a graph. The variable X_1 (pink R-Bot) is usually plotted as the horizontal X- axis of the graph, and the variable X_2 (Chemical BlueBerry) is plotted as the vertical, Y-axis. The complete problem we want to solve then is:

Maximize Profit (New Product Development) = $\$7X_1 + \$5X_2$ subject to the constraints:

$$4X_1 + 3X_2 \leq 240 \text{ (Electrical Engineering time available)}$$
$$2X_1 + 1X_2 \leq 100 \text{ (Chemical Engineering time available)}$$

Note that $X_1 > 0$ and $X_2 > 0$. These last two constraints are also called the non-negativity constraints. The first step in graphing the constraints is converting the constraint inequalities into equalities or equations.

Example--Figure 1: $4X_1 + 3X_2 = 240$ (Electrical Engineering time available)

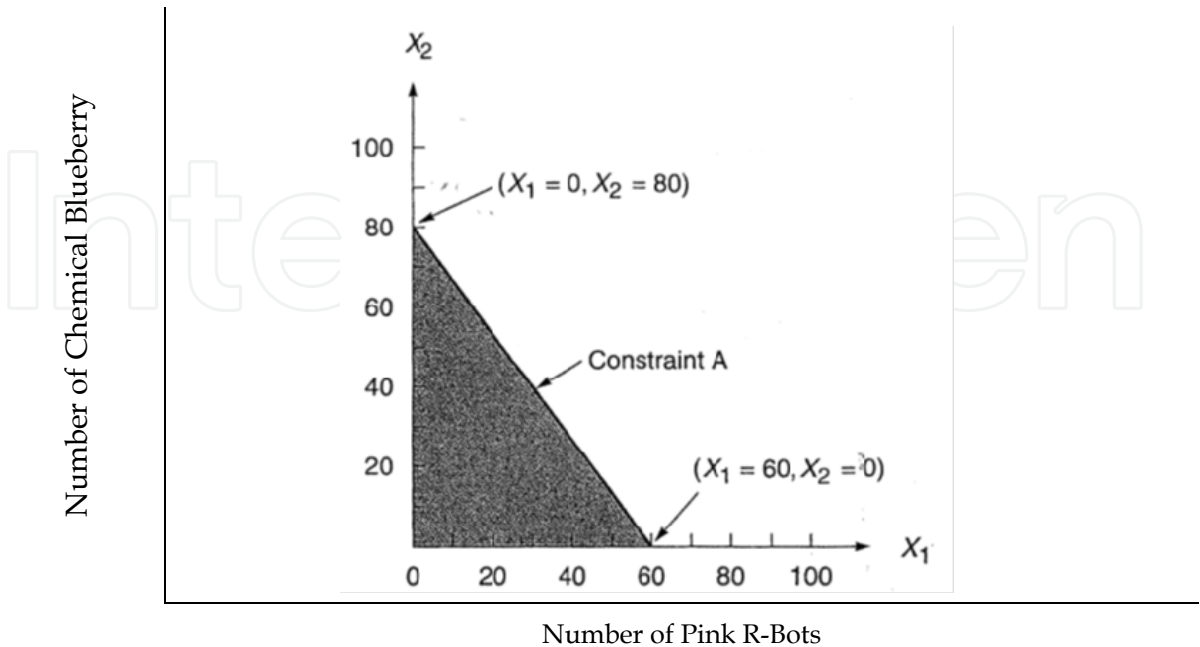


Fig. 1. Constraint 1.

Example-- Figure 2: $2X_1 + 1X_2 = 100$ (Chemical Engineering time available)

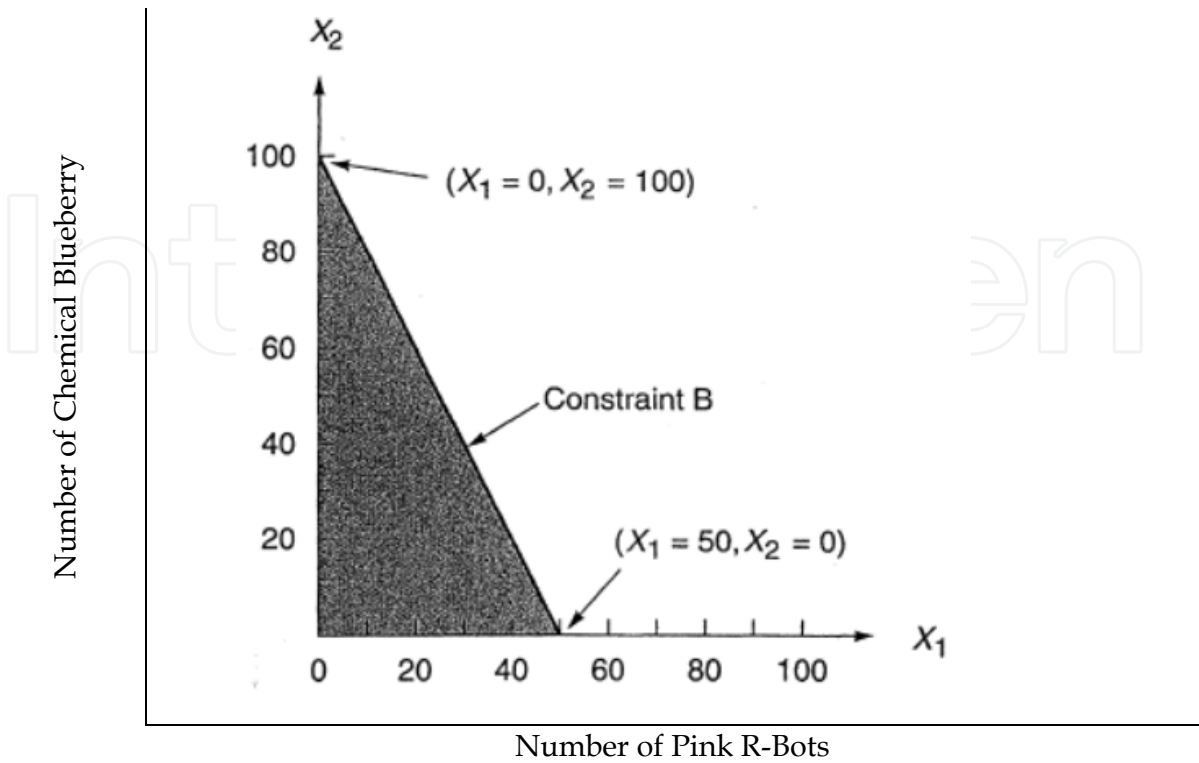


Fig. 2. Constraint 2.

Example-- Figure 3 below shows both constraints together. The shaded region is the part that satisfies both restrictions. The shaded region in Figure 3 is called the area of feasible

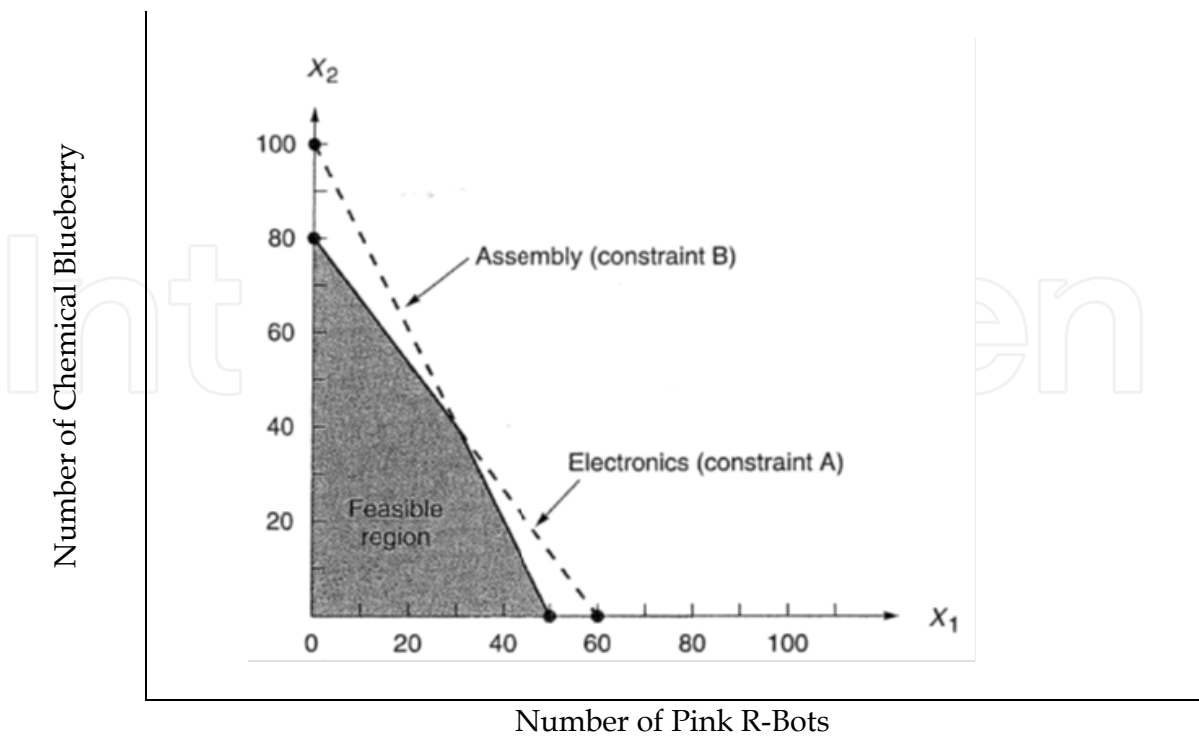


Fig. 3.

solutions, or simply the feasible region. This region must satisfy all conditions specified by the program’s constraints and is therefore the region where all of the constraints overlap. Any point in the region would be a feasible solution to the ABC Technology company question of where best to allocate the scarce hours of the chemical and electronics engineers. Furthermore, any point outside the shaded area would represent an infeasible solution.

Now that the feasible region has been graphed, we can proceed to find the optimal solution to the problem. The optimal solution is the point lying in the feasible region that produces the highest profit, or produces the greatest number of new products, or the greatest number of “disruptive innovations”. Once the feasible region has been established, several approaches can be taken in solving for the optimal solution. One method used is called the iso-profit line method. See Example – Figures 4 & 5 below.

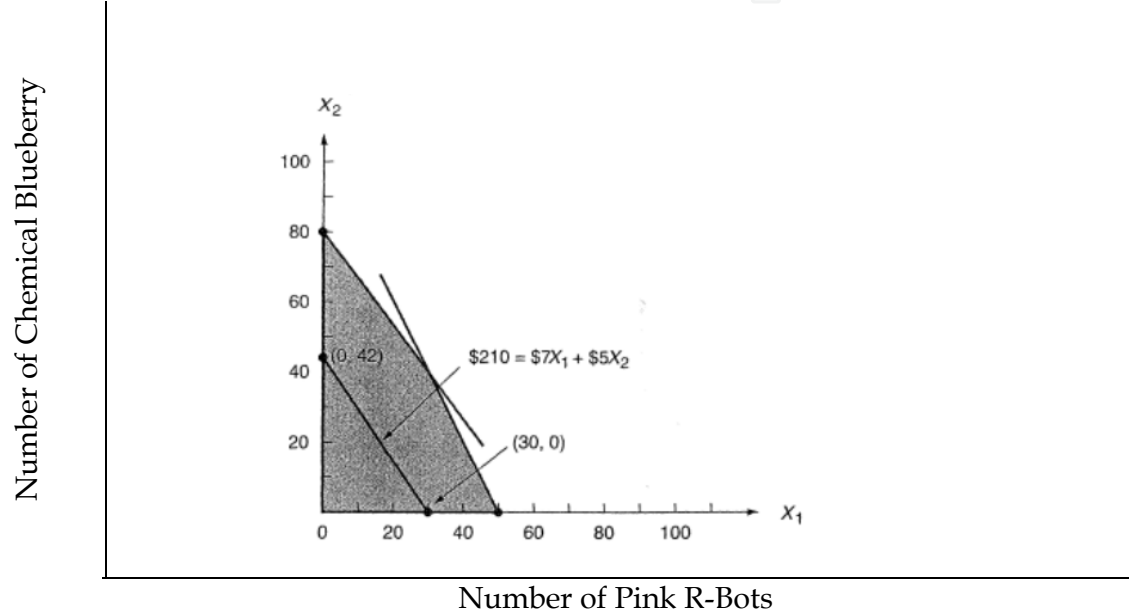


Fig. 4. A Profit Line of \$210 Plotted for ABC Technology Company.

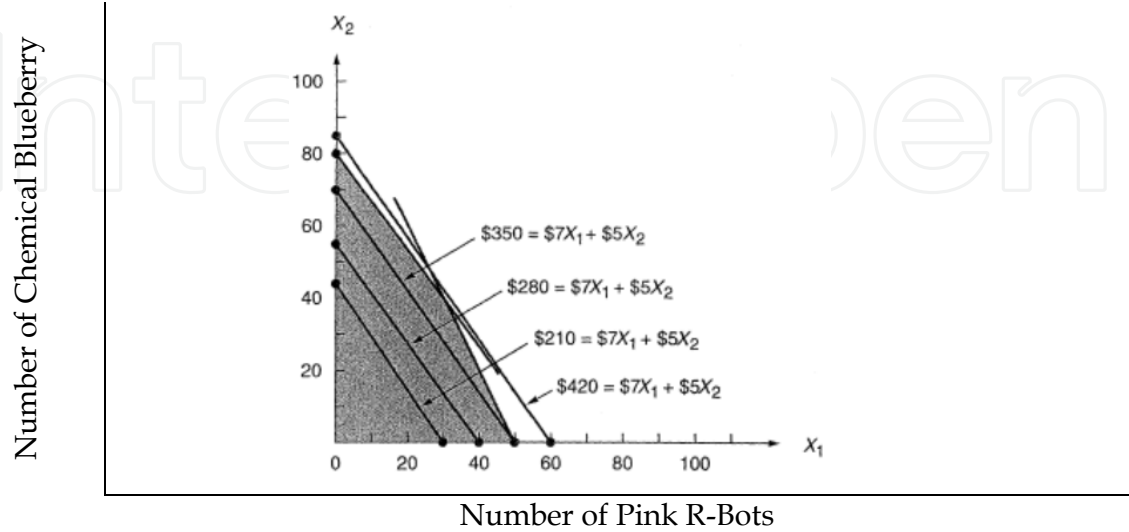


Fig. 5. Four Iso-Profit Lines Plotted for ABC Technology Company.

The last method that should be mentioned is the four corners of the feasible region method. This is shown in Example—Figures 6 & 7 below. In this method it is necessary to find only the values of the variables at each corner; the maximum benefit or optimal solution will lie at one (or more) of them. Once again we can see that (in Example—Figure 7) that the feasible region for ABC Technology Company problem is a four-sided polygon with four corner or extreme points. The points are labeled 1, 2, 3 and 4 on the graph. To find (X_1, X_2) values producing the maximum profit, we find out what the coordinates of each corner point are, then determine and compare their benefit levels.

Point 1: $(X_1=0, X_2=0)$ Benefit = 0

Point 2: $(X_1=0, X_2=80)$ Benefit = $\$7(0) + \$5(80) = \$400$

Point 4: $(X_1=50, X_2=0)$ Benefit = $\$7(50) + \$5(0) = \$350$

Corner point #3 needs to be solved algebraically. We apply the method of solving simultaneous equations to the two constraint equations:

$$4X_1 + 3X_2 \leq 240 \text{ (Electrical Engineering time available)}$$

$$2X_1 + 1X_2 \leq 100 \text{ (Chemical Engineering time available)}$$

To solve these simultaneous equations, we multiply the second equation by -2 to obtain:

$$-2(2X_1 + 1X_2 \leq 100) \text{ (Chemical Engineering time available)} = -4X_1 - 2X_2 = -200$$

And solve the two equations to obtain $X_2 = 40$ and therefore X_1 should equal 30. Therefore, point 3 produces the highest profit of any corner point, and point 3 has coordinates $(X_1 = 30, X_2 = 40)$ Benefit = $\$7(30) + \$5(40) = \$410$. Because point 3 produces the highest profit of any corner point, the optimal mix of resource allocation suggests making resources available for 30 units of pink R-Bots and 40 units of resources available for Chemical Blueberries, which solves ABC Technology Company's scarce resource allocation problem.

Another approach to solving linear programming problems utilizes the corner-point method. This technique involves looking at the profit at every corner point of the feasible region. The mathematical theory behind linear programming states that an optimal solution to any problem (that is the values of X_1, X_2 that yield the maximum variable of interest, which is generally profit, but could just as easily be new product introductions) will lie at a corner point, or extreme point of the feasible region. Therefore, it is necessary to find only the values of the variables at each of the corners. The variable of interest will be maximized at one of the corner points (see mathematical discussion and figure above).

There are two problems that arise in the deployment of scarce resources. The first is the 1) Activity Analysis Problem and 2) The Optimal Assignment problem.

The Activity Analysis Problem. There are n activities, $A_1, A_2, \dots, A_n$, that a company may employ, using the available supply of m resources, $R_1, R_2, \dots, R_m$ (labor hours, steel, etc.). Let b_i be the available supply of resource R_i . Let a_{ij} be the amount of resource R_i used in operating activity A_j at unit intensity. Let c_j be the net value to the company of operating activity A_j at unit intensity. Choose the intensities with which the various activities are to be operated to maximize the value of the output to the company subject to the given resources.

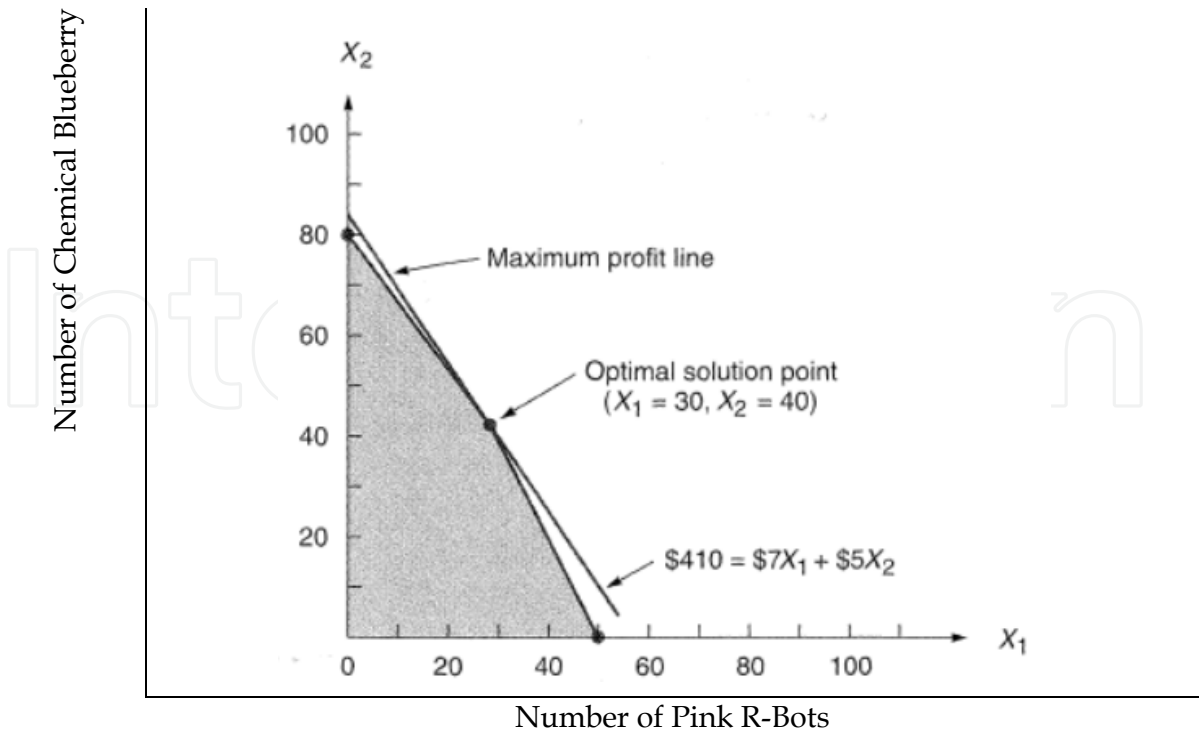


Fig. 6. Optimal Solution for ABC Technology Company.

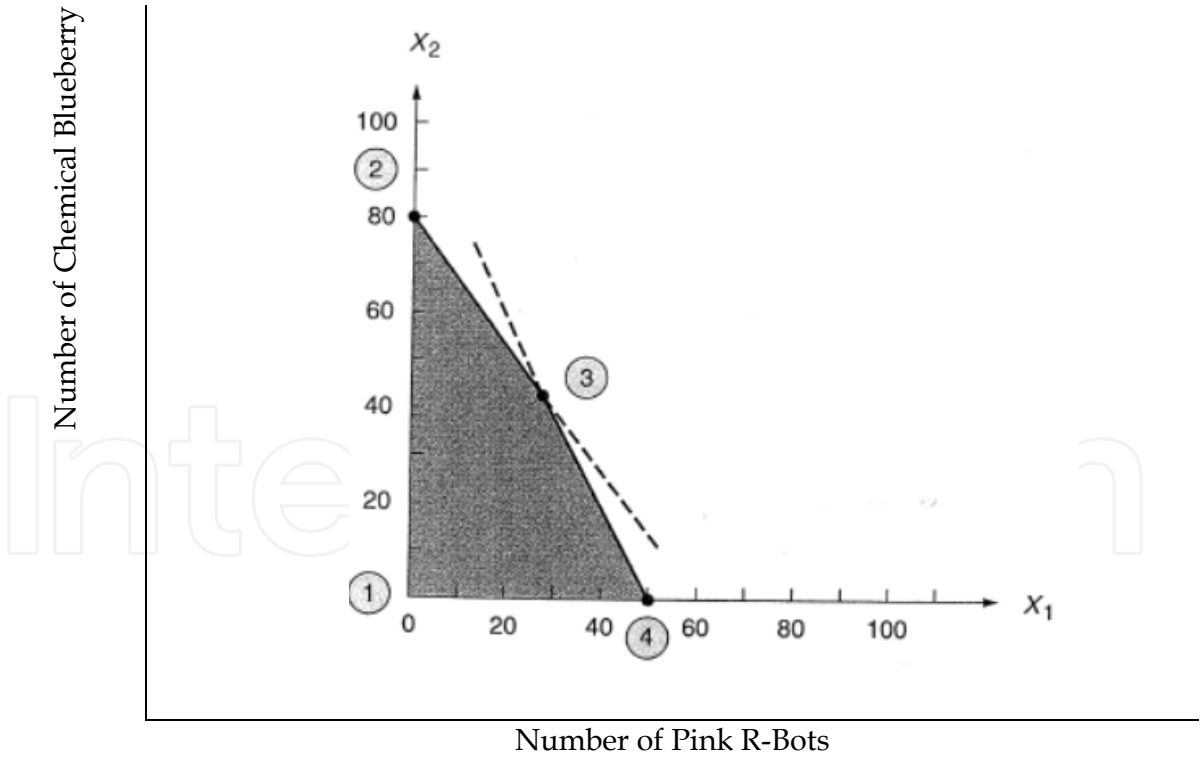


Fig. 7.

Let x_j be the intensity at which A_j is to be operated. The value of such an activity allocation is

$$\sum_{j=1}^n c_j x_j. \quad (8)$$

The amount of resource R_i used in this activity allocation must be no greater than the supply, b_i ; that is,

$$\sum_{j=1}^n a_{ij} x_j \leq b_i \quad \text{for } i = 1, \dots, m. \quad (9)$$

It is assumed that we cannot operate an activity at negative intensity; that is,

$$x_1 \geq 0, x_2 \geq 0, \dots, x_n \geq 0. \quad (10)$$

Companies want to: maximize (8) subject to (9) and (10). This is exactly the standard maximum problem that a company with scarce research and development resources needs to address and optimize in its desire to advance its innovation and research and development capabilities. Another critical issue that needs to be addressed with scarce resources, is that of optimally assigning these resources.

The Optimal Assignment Problem. There are I persons available for J jobs. The value of person i working 1 day at job j is a_{ij} , for $i = 1, \dots, I$, and $j = 1, \dots, J$. The problem is to choose an assignment of persons to jobs to maximize the total value.

An assignment is a choice of numbers, x_{ij} , for $i = 1, \dots, I$, and $j = 1, \dots, J$, where x_{ij} represents the proportion of person i 's time that is to be spent on job j . Thus,

$$\sum_{j=1}^J x_{ij} \leq 1 \quad \text{for } i = 1, \dots, I \quad (11)$$

$$\sum_{i=1}^I x_{ij} \leq 1 \quad \text{for } j = 1, \dots, J \quad (12)$$

and

$$x_{ij} \geq 0 \quad \text{for } i = 1, \dots, I \text{ and } j = 1, \dots, J. \quad (13)$$

Equation (11) reflects the fact that a person cannot spend more than 100% of his time working, (12) means that only one person is allowed on a job at a time, and (13) says that no one can work a negative amount of time on any job. Subject to (11), (12) and (13), we wish to maximize the total value,

$$\sum_{i=1}^I \sum_{j=1}^J a_{ij} x_{ij}. \quad (14)$$

This is a standard maximum problem with $m = I + J$ and $n = IJ$.

9. Terminology

The function to be maximized or minimized is called the objective function. A vector, x for the standard maximum problem or y for the standard minimum problem, is said to be feasible if it satisfies the corresponding constraints.

The set of feasible vectors is called the constraint set.

A linear programming problem is said to be feasible if the constraint set is not empty; otherwise it is said to be infeasible.

A feasible maximum (resp. minimum) problem is said to be unbounded if the objective function can assume arbitrarily large positive (resp. negative) values at feasible vectors; otherwise, it is said to be bounded. Thus there are three possibilities for a linear programming problem. It may be bounded feasible, it may be unbounded feasible, and it may be infeasible.

The value of a bounded feasible maximum (resp. minimum) problem is the maximum (resp. minimum) value of the objective function as the variables range over the constraint set. A feasible vector at which the objective function achieves the value is called optimal.

All Linear Programming Problems Can be Converted to Standard Form.

A linear programming problem was defined as maximizing or minimizing a linear function subject to linear constraints. All such problems can be converted into the form of a standard maximum problem by the following techniques.

A minimum problem can be changed to a maximum problem by multiplying the objective function by -1 . Similarly, constraints of the form $\sum_{j=1}^n a_{ij}x_j \geq b_i$ can be changed into the form $\sum_{j=1}^n (-a_{ij})x_j \leq -b_i$. Two other problems arise.

(1) *Some constraints may be equalities.* An equality constraint $\sum_{j=1}^n a_{ij}x_j = b_i$ may be removed, by solving this constraint for some x_j for which $a_{ij} \neq 0$ and substituting this solution into the other constraints and into the objective function wherever x_j appears. This removes one constraint and one variable from the problem.

(2) *Some variable may not be restricted to be nonnegative.* An unrestricted variable, x_j , may be replaced by the difference of two nonnegative variables, $x_j = u_j - v_j$, where $u_j \geq 0$ and $v_j \geq 0$. This adds one variable and two nonnegativity constraints to the problem.

Any theory derived for problems in standard form is therefore applicable to general problems. However, from a computational point of view, the enlargement of the number of variables and constraints in (2) is undesirable.

New Product Development Defined:

The new product development process can be defined as a good, service, or a good/service package, which was previously unavailable to customers, becoming available to the marketplace. From the perspective of a company, a new product also can be offering a good or service the company did not previously offer.

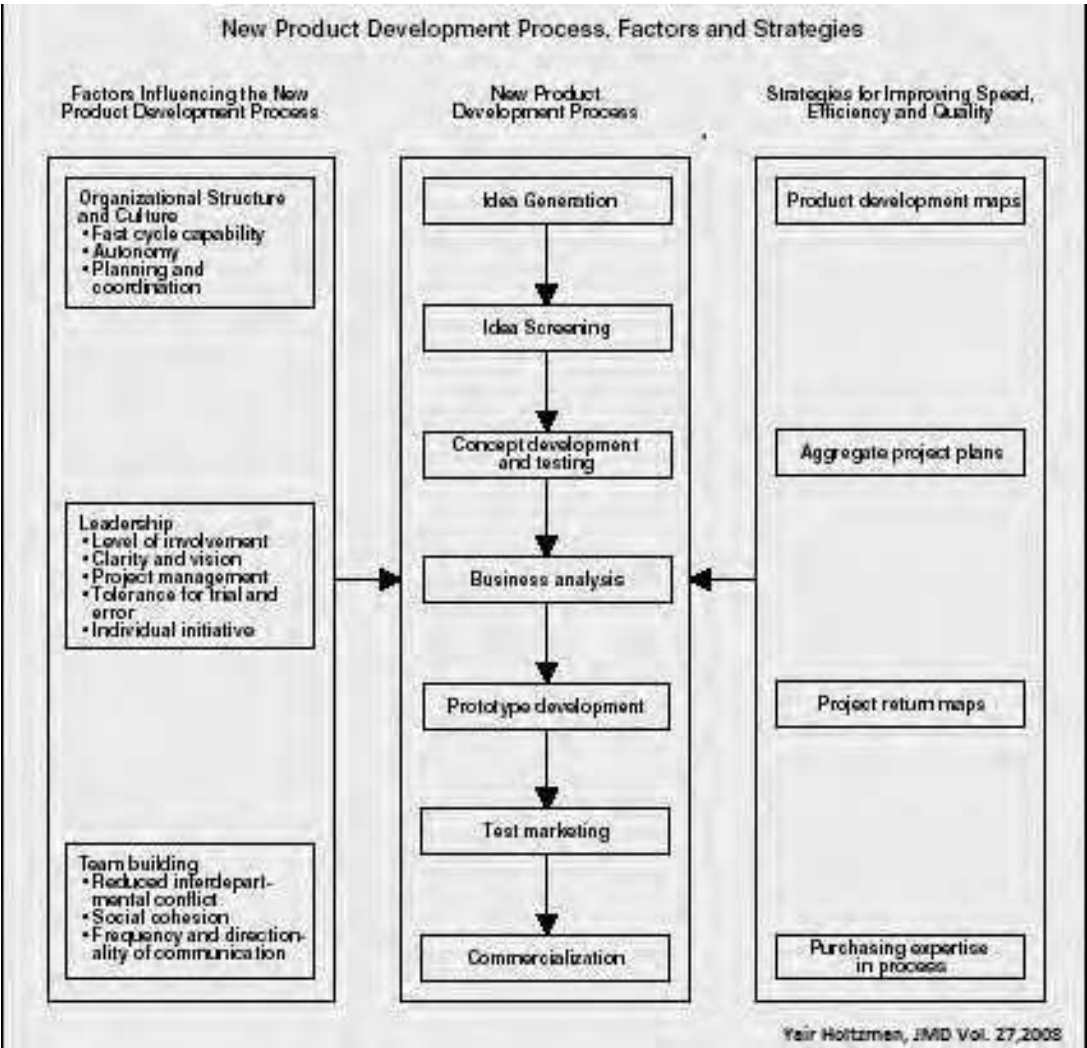


Fig. 8. New product development process, factors and strategies.

Effective research and development requires close and highly integrated links with many different parts of an organization that produces the product or service. Seamless integration and cooperation of various departments are essential to strategic new product development operations. Many new product ideas are based on existing products and are developed from within the production or service operations. It is not uncommon for a company’s research and development department to develop a new product, and for various reasons, the manufacturing department is unable to produce the product in an efficient and effective manner. An effective product development strategy links product development decisions with cash flow, market dynamics, product life cycle, and the organization’s overall capabilities. As a result, the screening process should extend to the operations function. Identifying products that are likely to capture market share, be innovative, be cost effective, and be profitable, but are in fact very difficult to produce, can lead to disappointment and failure rather than success. Motorola, for example, went through over 3100 working models before it arrived at its first working pocket cell phone. Optimal product development and innovation depends not only on support from other parts of the firm but also critically upon the successful integration of operations management decisions, from product design to maintenance.

Transparency and alignment of objectives and goals across all departments working on a research and development project is critical to the project's success. In general, it will enhance creativity and ownership by all, and reduce redundancies and inefficiencies. Figure 8 summarizes several of the new product development challenges and some of the required ownership "buy-in" required to tackle these.

10. Research and development defined

Research and development is sometimes referred to as "engineering" in the Life Sciences field since the design and development of medical devices is heavily dependent on activities related to one or more of the engineering disciplines. Research and development typically includes all engineering and testing activities beyond early-stage prototyping and final concept selection to the point when a product is ready to be released into production. A company's ability to transform an initial "proof of concept" prototype into a final product is central to its viability. The research and development process is critical for the success of companies that manufacture a technology product for several other tactical and strategic reasons as well. From a practical short term perspective, research and development:

1. Plays an instrumental role in defining how the original need is ultimately addressed.
2. Provides the engineering framework for developing a company's technology with the least amount of risk.
3. Facilitates the management of a primary driver of cost early in the company's life in terms of how personnel and other resources are utilized and managed.
4. Provides the foundation (processes, technology capabilities, and culture) that enables a company to continue innovating and developing future product iterations.
5. Often leads to critical insights related to the firm's intellectual property position.

From a longer term perspective, a strategic approach to research and development can also help a company:

1. Continually increase product differentiation, thereby solidifying market position and mitigating risk of competition.
2. Drive growth through new product innovation.
3. Develop new R&D capabilities.
4. Create a product development pipeline, which can make the company more attractive to investors and/or prospective acquirers.
5. Discover new markets and new cross-selling product capability.

There are various ways through which a company can decide to perform its research and development efforts. A study of the field of strategic research and development and new product development suggests that the most successful organizations use a research and development strategy that ties external opportunities to internal strengths and is linked with well-defined objectives. Well-formulated and executed research and development policies match market opportunities with internal capabilities and provide an initial screen for all ideas generated. Research and development policies can enhance strategy implementation efforts by either:

1. Performing research and development within the firm or contracting research and development to outside firms.

2. Using university researchers or private sector researchers.
3. Emphasizing product or process improvements.
4. Stressing basic or applied research.
5. Becoming leaders or followers in research and development.

In implementing different types of generic business strategies, effective and efficient interactions must exist between R&D departments and other functional departments. Lack of synchronization between marketing, finance and accounting, manufacturing, research and development, and operations departments can and should be minimized with clear policies and objectives.

Many firms struggle with the decision whether to acquire research and development expertise from external firms or to develop expertise internally. Based on my experience servicing companies in developing and harnessing their research and development capabilities, many companies have implemented the guidelines below relatively successfully as they make this decision:

1. In an industry where the rate of technical progress is slow, the rate of market growth is moderate, and significant barriers limit possible new entrants, in-house research and development is the preferred solution. By working internally, successful research and development will result in a temporary product or process monopoly the company can exploit.
2. If technology is changing rapidly and the market is growing slowly, a major effort in research and development can be very risky because it ultimately could lead to development of an obsolete technology or one for which there is no market.
3. If technology is changing slowly but the market is growing rapidly, there generally is not enough time for in-house development. The prescribed approach is to obtain research and development expertise on an exclusive or nonexclusive basis from an outside firm.
4. If both technical progress and market growth are occurring rapidly, research and development expertise should be obtained through the acquisition of a well-established firm in the industry.

A firm can take at least three different approaches to implementing research and development strategies. It can become:

1. The first to market new technological products.
2. An innovative imitator of successful products.
3. A low-cost producer of similar but less expensive products.

Of the various strategies, being the first firm to market new technological products seems most glamorous and exciting. Nevertheless, this can be a risky approach, particularly if the market does not appreciate the new differentiated product. By serving as an innovative imitator of successful products, a firm is able to minimize risks and start-up costs. This approach entails allowing a pioneer firm to develop the first version of a new product and demonstrate that a market exists. Laggard firms then develop a similar product. This strategy requires excellent research and development personnel and a strong marketing department.

A low-cost producer mass-produces products similar to, but less expensive than, products recently introduced. Recent trends indicate that research and development management have introduced an additional approach as some firms have begun to lift the proverbial veil of secrecy. In some instances, major competitors are joining forces to develop new products. Collaboration is on the rise due to new competitive pressures, rising research costs, increasing regulatory issues, and accelerated product development schedules.

11. Strategic innovation

Many organizations rely on random acts of creativity and innovation, which is not the way to drive successful innovation in the long run. In my experience, companies are best served by nurturing and facilitating a **strategic innovation approach**. Strategic innovation takes place on several levels and includes both traditional and non-traditional approaches to business strategy. First, it should consist of industry knowledge and foresight. This effort seeks breakthrough disruptive innovation while continuing to build core competencies. Secondly, a company should seek to understand its customer, provide insight, pinpoint unarticulated customer needs and delights, and deliver on these unmet needs. Lastly, strategic alignment should occur both internally, within the company, and externally, with customers and suppliers. This involves ensuring that all departments are aligned in terms of objectives. Successful strategic innovation involves exploring long term possibilities and practical implementation activities that lead to short term, measurable business benefit.

Strategic innovation is a holistic, systematic approach focused on generating disruptive and discontinuous innovations. Innovation becomes strategic when it is an intentional, repeatable process that creates a significant difference in the value delivered to consumers or the company. A strategic innovation approach initiative generates a portfolio of breakthrough business growth opportunities using a disciplined yet creative process. Based on my findings, seven key components lead to successful strategic innovation. First, managing the innovation process involves selectively combining traditional and non-traditional approaches to business strategy. Second, industry knowledge and foresight means the key decision makers and technology leaders within a company understand the complex forces driving change, including emerging and converging trends, new technologies, competitive dynamics, and competition. Third, strategic alignment means building support for the initiatives from the senior leadership team, within the company, and with any related stakeholders. Fourth, customer insight, including understanding your customer, what they value, and what delights them, is critical to the success of any new product development initiative. Fifth, technologies and competencies are the set of internal capabilities, organizational competencies, and assets that can be leveraged to deliver value to customers. These assets include technologies, intellectual property, brand equity, and strategic relationships. Sixth, the buy-in of the leadership of the entire organization is essential for implementation of strategic innovative ideas to take root. Seventh, effective and efficient implementation of a product from inspiration to completion requires disciplined follow through at all phases of the project. It is challenging to develop creative, visionary thinking; it is far more difficult to successfully implement that thinking in a way that creates meaningful business impact.

The managed innovation process extends and covers all of the activities from initial brainstorming sessions through implementation. When we discuss strategic innovation, the

term “implementation” includes a wide range of activities. These include transition to specific projects, reallocation of resources, properly incentivizing key employees, and creating an environment that encourages creativity and innovation and does not penalize employees for failure. Implementation demands span well-beyond the scientific and technology departments to encompass technical product testing, value proposition development, a clear marketing campaign, consumer-based rapid prototyping and testing, brand development, business case construction, effective marketing channels, a supply chain, and broad organizational buy-in. In practice, this can take many forms. My experience has included many companies that utilize approaches involving facilitated workshops sessions. These sessions force cross-functional teams to look beyond the expected next step. Implementation can mean successfully bringing a new product to market or increasing market share, which is achieved by utilizing a new development strategy or creating a more robust technology; regardless, the process needs to be carried through to completion. In the process, companies are able to seek out disruptive creative ideas that have the potential to cross pollinate and lead to new levels of creativity.

In order for the managed innovation process to have a chance at success, both the senior leadership team must buy-in completely and all affected parties should contribute. This complete representation will consist of a broad cross-section of the company and any other stakeholder in the supply chain that shares the same vision or desire for the project to succeed. I have seen this work successfully in the biotechnology industry and fail miserably in the automotive industry. The key difference was that the biotechnology company had clearly aligned all critical stakeholders, internal and external, and in the automotive example, the tier one and tier two suppliers were not brought into the fold on these new innovative projects until they were actually provided with a finished product. These tier one and tier two suppliers were then asked to incorporate the new component product on their production lines and send the finished assembled product back to Detroit. There were problems in design that did not allow the product to be ready for mass production, and the product underwent several rounds of iterations.

Active cross-functional participation in the new product development process builds strategic alignment and buy-in among key stakeholders both within an organization and externally. This alignment strengthens the organizational buy-in, creates ownership and excitement, accelerates any decisions that need to be made along the way, and facilitates successful implementation. Strategic alignment is absolutely critical for operational success as it enables cross-functional decisions and agreement on difficult issues surrounding implementation activities, such as resource allocation, competencies, and ownership of parts of the project. Furthermore, for the project to be successful, it is essential that stakeholders are continuously engaged in a meaningful manner from the inception of the idea throughout the implementation process.

One of the most important components of successful strategic innovation is for company leadership to understand the drivers, trends, enablers, and threats to the industry in which the innovation is being undertaken. Visionary organizations typically establish a process for monitoring the complex interplay of key trends that could potentially impact their business. Best-in-class innovators know how to evaluate the various forces in the global marketplace, and as a result, expose potential opportunities in the “white space” and develop robust and effective strategic innovation.

12. Product differentiation: what does it mean and why is it important?

Product differentiation exists when customers genuinely perceive a certain firm's product to be more valuable than other firms' products. For example, customers who purchase BMWs and believe that BMW builds the "ultimate driving machine" are purchasing an automobile that they perceive to be superior to all others on the market. Although differentiation can have several different bases, in the end it is always a matter of customer perception. The attributes of product differentiation include characteristics of the product or service provided, the relationship between a firm and its customers, and connections and interrelationships between firms. The last point might not be as clear as the first two; it relates to the firm's product mix, distribution system, supply chain, and level of customer service and support. A company's first line managers maximize product differentiation through creativity, coordination, and transparency.

Why is product differentiation valuable? One reason is that it enables a firm to set its prices higher than it would otherwise be able to charge its customers.

Each of the bases of product differentiation identified can be used to exploit environmental opportunities, capture market share, or even establish the company as a dominant leader in that space. The rarity and uniqueness of bases of product differentiation differ widely. Highly imitable bases of product differentiation include product features. Somewhat imitable features include product mix, interconnections with other firms, and product customization. Extreme difficulty lies in imitating bases of product differentiation that include disruptive technologies or new-to-world products or capabilities. Organizations that have strategically integrated product differentiation throughout the company do indeed develop capabilities that are very robust and difficult to imitate.

Implementation of a product differentiation strategy involves connecting technical efforts to the business as a whole, which is challenging for research and development management of large companies. In general, integrated and synchronized management of the organizational structure, management controls, and well defined and flexible incentive policies can help foster successful strategic new product development and research and development. It is very common for companies implementing product differentiation strategies to use cross-divisional and cross-functional teams in addition to teams focused exclusively on a particular product development effort. Based on my findings, managerial controls that provide free managerial decision making within broad decision-making guidelines can be helpful in providing robust implementation of product differentiation strategies. Furthermore, employees that are incentivized to take some risks through compensation policies that encourage creativity and innovation are more successful in bringing product differentiation strategies and products to market.

For many years it was thought by leaders in the innovation and new product development world that a company had to choose between unique, innovative, top notch products and products that are relatively inexpensive. I spent several years consulting to the automotive industry where, in general, it was thought that plants could not simultaneously build low-cost and high quality automobiles. Between 1994 and 2004, I had the opportunity to visit 54 automotive plants throughout the world that assembled either completed automobiles or large components that go directly into the completed automobile. What I observed at the time the research was done was that there were four plants that were able to have both low

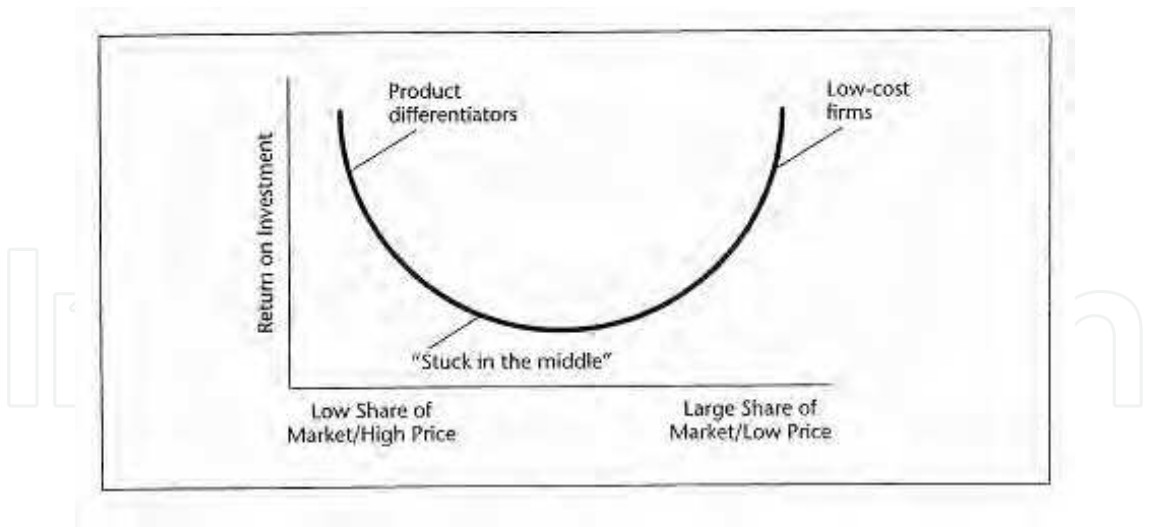


Fig. 9. Simultaneous implementation of cost leadership and product differentiation competitive strategies: being "Stuck in the Middle".

Cost leadership	Product differentiation
Organizational structure 1. Few layers in the reporting structure 2. Simple reporting relationships 3. Small corporate staff 4. Focus on narrow range of business functions Management control systems 1. Tight cost-control systems 2. Quantitative cost goals 3. Close supervision of labor, raw material, inventory, and other costs 4. A cost leadership philosophy Compensation policies 1. Reward for cost reduction 2. Incentives for all employees to be involved in cost reduction	Organizational structure 1. Cross-divisional/cross-functional product development teams 2. Willingness to explore new structures to exploit new opportunities 3. Isolated pockets of intense creative efforts Management control systems 1. Broad decision-making guidelines 2. Managerial freedom within guidelines 3. Policy of experimentation Compensation policies 1. Rewards for risk-taking, not punishment for failure 2. Rewards for creative flair 3. Multidimensional performance measurement

Fig. 10. The organizational requirements for implementing cost leadership and produce differentiation strategies.

costs and very high quality. I am confident that if I visited all 54 plants today, a larger percentage would be able to deliver both low cost and very high quality. The reason I believe that this tradeoff is becoming less prevalent than it was twenty years ago is primarily for the following three reasons. First, plants are employing best manufacturing technology and practices (Six Sigma, lean manufacturing, computerized robots, laser guided paint machines, etc.). This is coupled with highly participative, group oriented team ownership, including participative management, team production, and total quality management. Second, employees have a clear sense of ownership and take pride in their work product. Third, the employees demonstrate a tremendous amount of loyalty and commitment toward the plant they work for, a sense of loyalty and pride that translates to fewer errors and overall best quality and better work environment.

These four plants had clearly demonstrated that the traditional tradeoff assumed in the industry should not necessarily be taken for granted. Firms can simultaneously implement cost leadership and product differentiation strategies if they learn how to manage the contradictions inherent in these two strategies. Successful management of these two seemingly contradictory strategies depends upon working through socially complex relations among employees, between employees and the technology they use, and between employees and the firm they work for. Successfully managing these challenges can result in both of these strategies complementing each other and fueling further cost reductions and increased differentiation. Connecting scientific and engineering efforts to business objectives is a significant challenge for research and development and high technology manufacturing management. Technical employees who are brought into the fold and the “know” are able to make good decisions, and they may be further motivated to contribute all of their knowledge and creativity and support organizational objectives far better than they otherwise would.

13. The strategic importance of product and service development

As illustrated in Figure 11, product and service development is viewed as increasingly important from a strategic point of view. From a market perspective, international competition has become increasingly intense. In many markets, there are a number of competitors bunched together in terms of their product and service performance. As a result, even small advantages in product and service specifications can have a differentiating impact on competitiveness and ultimately, product survival. This has made customers much more sophisticated in exercising their choice and often more demanding in terms of wanting products and services that fit their specific needs. Furthermore, markets are becoming more fragmented. Unless companies choose to follow relatively narrow niche markets, they are faced with developing products and services capable of being adapted in different ways to different markets. To further exacerbate the technical challenges, product and service life cycles have become shorter. Therefore, introducing new products and services in an efficient and effective manner allows companies to have an advantage over the competition. Because competitors respond by doing the same, the situation escalates.

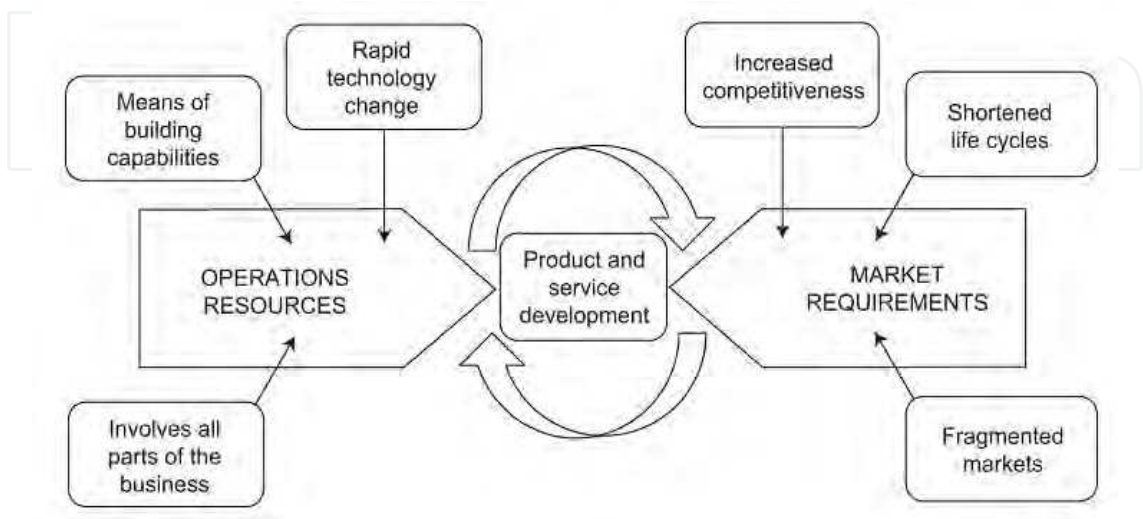


Fig. 11. The increasing strategic importance of product and service development.

An additional set of pressures affect the operations resources that develop and deliver new products and services. Perhaps most importantly, rapid technology changes have affected most industries. Primarily because of the scale and pace of such technological developments, it has become increasingly obvious that effective product and service development places responsibility on every part of the business. Marketing, purchasing, accounting, and operations are all an integral part of the organization's ability to develop products and services effectively and efficiently. Every part of the business is now faced with the question of how it can deploy its particular competencies and skills toward developing innovative, value-adding products and services in an efficient and effective manner.

Stages of Development

The way in which organizations develop products and services is as varied as the products and services themselves. Furthermore, what companies specify as a formal product or service development methodology, as compared to what happens in reality, are usually very different things. Nevertheless, in my experience, the ideas below seem to have found wide acceptance amongst product development companies.

Figure 12 below outlines the development process as it moves through a series of stages. As development progresses through the various stages, some steps might be unnecessary on certain projects, while other steps are repeated multiple times. At the beginning of this process, there are stages concerned with collecting ideas and generating product and service concepts, and toward the end of the process, there are stages concerned with specifying the detail of product or service specifications.

As the development process moves through these stages, the number of alternative design options is reduced until one final design remains. The process often includes decision points that screen out options viewed as unsatisfactory.

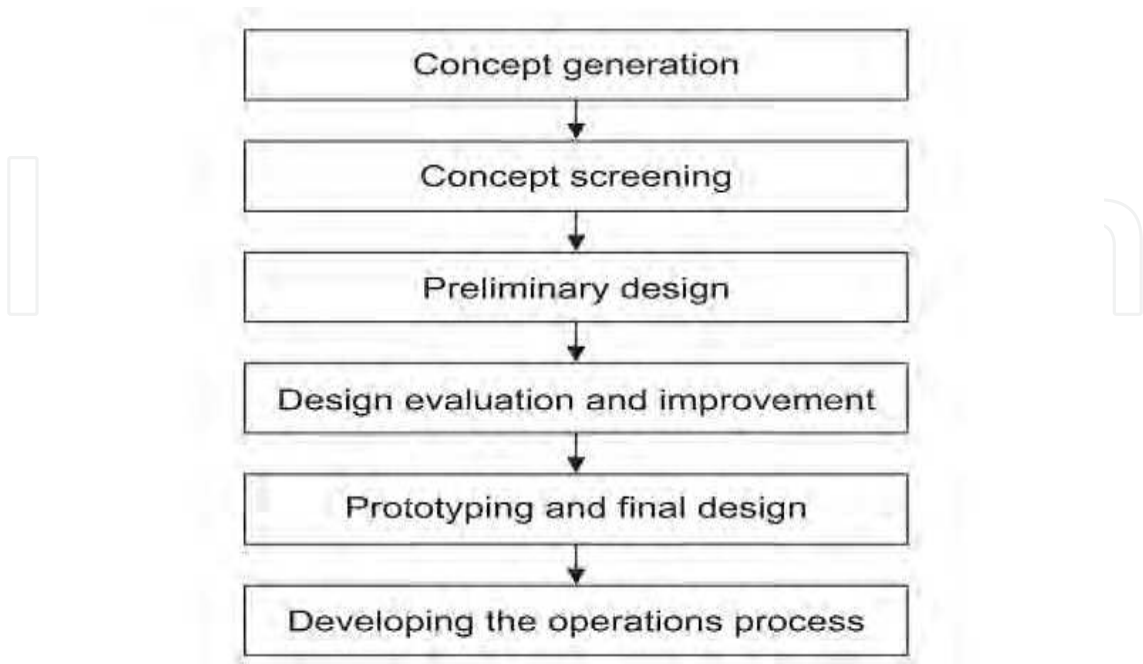


Fig. 12. A typical "stage model" of the product and service development process.

The possible design options are then reduced to a very small set of possible research and development outcomes, and engineers move from a state of uncertainty to a state of increasing certainty. One consequence of this is that the ability to change the design set gets increasingly difficult and limited. Making changes at the end of the development process can be considerably more expensive than making them at the beginning of the development process. Therefore, adding value early on in the research and development process is critical to success.

14. Creating efficiency in research and development and adding value early in the process

In their ongoing desire to become more efficient, many research and development organizations largely focus on reducing administrative inefficiencies, such as burdensome approval processes, lack of information, and meetings that are unproductive or unnecessary. Yet, they tend to overlook the bigger issue of engineering inefficiencies, which are caused by problems such as shifting design requirements, poor integration of design components, and post-production design changes. Although engineering and research and development inefficiencies consume substantial time and resources -- and have a much bigger impact on the bottom line -- they are often ignored because they are more complex and challenging to address. In some cases, they are not even recognized as a problem.

Should companies focus more attention on reducing engineering and research and development inefficiencies and adding more value early in the design process? Or should they accept the status quo and focus their efforts elsewhere?

Here is the debate that many business leaders and research and development executives are wrestling with. Should they focus more attention on engineering waste and accelerate engineering value? The best way to improve engineering efficiency is to avoid unnecessary design changes, minimize rework, and improve coordination between design and manufacturing from the get-go. Reduced engineering waste will lower design costs, accelerate development, and improve overall competitiveness.

Many research and development organizations do not view manageable inefficiency as a waste, but instead as a value-added activity necessary to get the design right. Nevertheless, based on my experience, excessive engineering effort is a clear indicator of inefficiency and can be reduced sharply without an adverse effect on design outcomes.

For example, poorly defined requirements early in the design cycle can cause excessive low value adding effort in later phases, which ultimately increases costs and slows work down. Other common causes of manageable excessive engineering effort include:

Lack of integration. R&D organizations are becoming more and more sophisticated in their use of computer-aided tools to design and model product parts. However, disconnects still can occur when individual design efforts are not tied into a requirements management process that ensures the separate components will ultimately work together. Not having the right tools, processes, people, or data to achieve the necessary integration can contribute to excessive non-value adding activities.

Poor synchronization across design groups. Different design teams tend to work at different speeds. Unless work is scheduled and prioritized, some groups inevitably fall

behind or find themselves waiting on others. This is particularly challenging when the time comes to test that various components work together – especially if some components are mechanical while others involve software or are electrical.

Design by committee. Building consensus around decisions can be a valuable exercise. At the same time, excessive deliberation and lack of clearly delineated decision-making roles is counter-productive and can make it difficult or impossible to meet product development deadlines.

Lack of cross-functional integration. Research and development needs to bring other functions into the development process as early as possible. For example, failure to get the manufacturing organization involved can lead to inadequate tools and shop floor processes. Similarly, failure to involve the after-market service organization can create costly support problems for the company and its customers. The best design in the world is useless if it cannot be built and properly supported.

One reason engineering inefficiency is hard to fix is because it is hard to see. The right diagnostic tools can help decision-makers visually analyze engineering data to better determine how much engineering effort is unavoidable and how much can be eliminated. Tools and techniques from lean manufacturing and Six Sigma can then be applied to help address the root causes of manageable churn and add more engineering value in the early stages of the design cycle.

Manufacturing businesses around the world have been operating in a severe cost-cutting environment for more than a year, and the pressure to keep costs down is unlikely to abate any time soon. In fact, for many global manufacturers, cost reduction and limited research and development funding have become a basic business requirement.

Of course, most manufacturing companies do not have the luxury of cost-cutting their way to prosperity and growth. At some point, they will need to invest in new products, markets, and growth opportunities. Achieving sustainable growth and innovation in the face of limited research and development funding requires improved capabilities. Sticking with the status quo is simply not an option.

Attacking engineering inefficiency to significantly improve high value add research and development efficiency, while, at the same time, improving research and development performance, must be considered. For example, a global specialty chemical manufacturer recently identified 50,000 engineering labor hours that could be better spent developing new products. Similarly, a global automotive manufacturer identified millions of dollars in annual engineering labor that could be used more efficiently and eliminated over a dozen of steps in quality control and routine testing.

Identifying and reducing engineering churn can enable a company to redirect wasted resources and effort to activities that create value for the business and improve its overall competitiveness in the marketplace.

Automotive, process, and industrial products manufacturers share a common characteristic: they all manufacture highly engineered products. For these businesses, the benefit opportunities of attacking waste in engineering are the same as for attacking waste in manufacturing operations – reduced cycle time, increased throughput, higher product quality, and lower costs.

Unfortunately, the drivers and impact of non-value activities and inefficiencies in engineering tend to be less apparent than in manufacturing operations, where physical scrap, inefficient flows, and poor production quality often are readily visible. The good news is that analytical tools are available to help companies in their efforts to identify and address the damaging effects of engineering waste.

The payoff for auto, process, and industrial manufacturing companies can be relatively high since engineering costs comprise such a large percentage of their overall cost structure. For example, a global automaker recently identified hundreds of man-months of wasted development time per full vehicle program, which represented millions in excess research and development costs. That is a level of waste and inefficiency that today's manufacturers simply cannot afford if they are to survive in the highly competitive global manufacturing environment.

15. Marketing's role in strategic research & development optimization

Marketing plays a critical role in the development, success, and optimization of strategic research and development in new product and process development.

All businesses face different sets of challenges: challenges in internal operations, in the industry, in the economy, in the marketplace, and in growth stages. Starting a new business can be difficult, time-consuming, and risky. Marketing research and strategy development at this stage are as important as raising finance for the business. A growing business, in addition to managing the growth process, must deploy and leverage new technologies while developing strategies to increasing its share of the market. It must juggle the developing of brands, the management of cash flow, and the development of an effective distribution and supply chains. Established businesses must develop new income streams to sustain profitability in a rapidly changing competitive market, consistently define new markets and develop synergistic partnerships.

Historically, in the pharmaceutical industry, customer-led research and development has not been practiced so rigorously. Pharmaceutical companies set research and development priorities based on the opportunity for scientific discovery combined with long-term revenue forecasts- notably, not profit forecasts- that promise attractive commercial gains. They seek the customer's input- from physicians, payers, and patients- usually only after a product reaches the late-stage pipeline; even then, the feedback influences only launch strategies and market positioning. Moreover, such customer input is heavily focused on physicians, such as the factors that influence their prescriptions. The payer's perspective is largely restricted to reimbursement negotiations. It is rarely an input for setting research and development priorities, and almost never in the early stages of the pipeline, in the labs and clinics. In effect, pharmaceutical companies seldom undertake a rigorous assessment of what payers will be willing to pay for compared to alternative treatments before deciding what to research.

In the future, pharmaceutical companies will need to listen early in their research and development efforts to the voice of customers, especially payers. While a pharmaceutical company cannot design products tailored to customer specs, as SAP does, it can guide its research and development closer to customer needs. That shift is imperative. As payers consolidate, they are becoming more powerful and cost conscious, demanding hard

evidence that their reimbursement dollars are well spent. By identifying which health outcomes payers are more willing to reimburse, pharmaceutical companies can more closely align research and development priorities with market realities. This new approach will be challenging, and even a little frustrating, because payer priorities change over time. But pharmaceutical companies must listen, respond, and evolve based on what their customers are saying.

At all of these stages, businesses need a guide who understands these issues and can work in partnership with them to develop effective solutions to the challenges.

How do you know if you are Innovating Effectively?

Innovation is not for the risk averse. For example, in the context of the Life Sciences environment, there are a lot of moving parts connected to effective and efficient research and development delivery. Emphasis on quality of care, adhesion to regulation, increasingly challenging reimbursement policy, and the risk of litigation heighten the stakes relative to introducing change in the medical environment. How can cutting edge technology successfully migrate into healthcare without also being a risky proposition? How is the landscape changing? Or, more importantly, how can you find out how it is changing?

The answer is preparation, iteration, and prototyping as driving components of the development process. This discussion is beyond the scope of this text, but according to the experiences I have had in the research and development and new product development arena over the past seventeen years, I recommend focusing on methods and strategies for proactively identifying and responding to obstacles to success relative to technology adoption, including:

1. Extracting user needs beyond Voice of the Customer (VOC).
2. Utilizing effective co-development with high value-add supply chain partners.
3. Effectively identifying and speaking to ALL of your stakeholders .
4. Making sure your requirements are the RIGHT requirements.
5. Having the power of an effective and efficient process of development optimizing across the most critical variables, which could require substantial iteration in the development process.

16. Conclusion

Competitive markets and demanding customers require updated and 'refreshed' products and services. Even small changes to products and services can have an impact on competitiveness. Markets are also becoming more fragmented, requiring product and service variants developed specifically for custom market needs. Simultaneously, technologies are affording researchers increased opportunities for their exploitation within novel products and services. It is critical to appreciate that the successful development of products and services is inextricably intertwined with efficient and effective and ideally optimized development of processes that produce them. Product and service development success is governed by successful and efficient research and development processes. In order to achieve effective and efficient research and development and product innovation it is not uncommon for firms to use cross-functional teams, together with teams focused exclusively on a particular product differentiation effort.

Establishing the sense of connectivity for scientists and engineers with the overall business strategy is absolutely critical to achieve efficiency and effectiveness in the research and development efforts of a firm. Scientists who are connected to the business strategy will have a better clarity as to what to do in certain situations and create a valuable sense of ownership that the employees value. Clear transparency of business strategy shared across the organization will create enhanced ownership, loyalty, and creativity by most employees. Translating the overall business unit or plant objectives into goals and objectives at the lower levels is critical to create that sense of transparency and ownership. Clear and open communication both from the business leadership down and from the lower level scientists up to senior management will quickly facilitate the understanding of problems, constraints, and new opportunities and catalyze strategic innovation.

There is no single model that companies utilize in new product development; in fact, there are many. Nevertheless, these share some common denominators including concept generation, concept screening, preliminary design, design evaluations and improvement, prototyping and final design, and developing the efficient and effective operations process to deliver successful outcomes.

A visionary research and development, or new product or service development, that is not linked early on to excellent operational and governance processes, cannot be implemented. Conversely, operational excellence may lower costs, improve quality, and reduce process and lead times, but without a strategic research and development vision and guidance, it is unlikely to enjoy sustainable success from its operational improvements alone. High performance operating processes in research and development are critical, and when combined with proactive implementation and governance, will result in successful and strategic research and development that could serve as a sustaining advantage to companies in the near and long term.

Most companies face constraints on the resources at their disposal to innovate and conduct research and development; therefore, they need to allocate these resources selectively to achieve the outcomes they seek. We have introduced linear programming in this chapter; it is a valuable tool in tackling problems involving resource constraints.

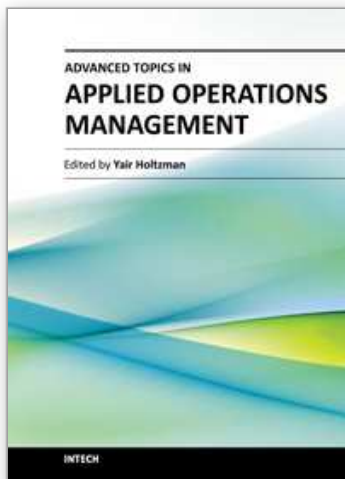
This chapter has discussed several of the benefits of developing and nurturing a strategic research and development strategy. The benefits are not only external, in gaining the upper hand on the competition, but also internal. Internally, employees demonstrate greater loyalty, creativity, and a greater understanding of what the company is trying to achieve. If some of the tools and methodologies discussed in this chapter are placed into practice, management will find that these continue to fuel further strategic innovative behavior and that the overall benefit is compounded over time.

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The chapters in Advanced Topics in Applied Operations Management creatively demonstrate a valuable connection among operations strategy, operations management, operations research, and various departments, systems, and practices throughout an organization. The authors show how mathematical tools and process improvements can be applied effectively in unique measures to other functions. The book provides examples that illustrate the challenges confronting firms competing in today's demanding environment bridging the gap between theory and practice by analyzing real situations.

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