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A FRAMEWORK FOR ASSESSING PRODUCT INNOVATION STRATEGIES IN A COMPETITIVE CONTEXT

Patrick J. Rondeau and Bhal J. Bhatt

INTRODUCTION

The development of new products capable of satisfying customer demands on a timely basis has become a priority for firms seeking to improve their competitive advantage in a global context.
However, this challenge has become highly complex due to a growing diversity of both products and processes, higher costs, and unprecedented considerations for quality and service (Bolt, 1988). Despite knowing a great deal about both the characteristics of successful firms and new product development processes, little is known regarding requisite guidelines for successful strategies in product development.

Kantrow (1980), among others, has identified market, customer, organizational, and managerial characteristics of firms that have been successful in new product development. Others have attempted to identify the product, manufacturing, and information technologies that surround successful product development processes

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(Morton, 1983; Stoubaugh and Telesio, 1983; Wheelwright, 1984; Zirger and Modesto, 1990). In both cases, the focus has been on describing the general activities that firms have engaged in to improve product development success as well as overall competitive advantage.

Hence, a critical need exists for a framework to guide the creation of product development strategies that is based upon an examination of the relationship between product innovation and the competitive nature of technologies. We propose the construction of such a framework through an integration of Tushman and Nadler's (1986) levels of innovation with Johnson's (1987) levels of technology to create a 3X3 matrix of product innovation/technology positions. Within this framework, the product development process is discussed and an innovation index is proposed by which a firm may assess and preposition product performance.

LITERATURE REVIEW

Johne and Snelson (1989) have classified the development of new products in terms of either *old product development* (OPD) or *new product development* (NPD) efforts. OPD is primarily concerned with protecting or extending the market share of existing products through their redevelopment or revision to better fit current market demands. NPD is concerned with the creation and development of totally new products that define new markets or capture specific segments of existing markets not previously addressed by a firm.

In a majority of cases, however, new products are essentially "spin-offs" of pre-existing families of products and contain only minor improvements over their predecessors. As such, relatively few new products may be classified as truly new and revolutionary in nature. Furthermore, when comparing OPD versus NPD processes, NPD processes will often carry a higher risk of failure than will OPD processes. This is primarily because OPD efforts are: (1) normally based upon a successful line of existing products; and (2) often utilize proven technologies and processes in which the firm has had extensive prior experience (Johne and Snelson, 1989).

A firm's initial reaction might be to embrace and exclusively pursue the apparent safety of an OPD strategy. However, a long-term failure to pursue totally new products might also prove disastrous if competitors were to succeed in their NPD activities. A firm must therefore identify and achieve a proper balance between its need to attain greater technical synergies with its need to produce truly new and innovative products capable of defending or expanding market share (Link, 1987; Paul, 1987). This may require firms to simultaneous engage in the pursuit of both NPD and OPD activities. Accordingly, a need for the subsequent development of better methods for assessing and understanding the innovation/technology relationship within and between firms clearly exists to enable the creation of more effective long-term product development strategies.

LEVELS OF PRODUCT AND PROCESS INNOVATION

Tushman and Nadler (1986) describe product and process innovation as occurring on one of three levels. The first is *incremental innovation* where added features, new versions, or extensions to existing product lines are implemented in small steps. While this often results in lower costs of product development and reduced risk, it may also yield a lower return on investment (ROI) for the firm. However, when managed well these smaller but more consistent product and process improvements (i.e., learning curve effects) can add up to create significant gains by substantially extending old product's lives.

The second, *synthetic innovation*, occurs when the firm combines existing technologies and ideas in new and never previously done ways to create significantly new products. Synthetic improvements usually set new standards in some way for an existing product class and often result in sharp improvements in process scope, volume, or capacity (i.e., medium innovation steps). As a result, they are associated with a medium level of potential cost, risk, and ROI.

The final level, *discontinuous innovation*, involves the creation of significantly new technologies or ideas resulting in the development of previously non-existent products (i.e., large innovation steps). Totally new process methods and technologies are often required for product development and manufacture. Successful discontinuous innovation may result in the creation of totally new products which may render entire classes of products obsolete. Accordingly, discontinuous innovation is usually associated with the highest potential level of product costs, risks, and ROI.

THE COMPETITIVE NATURE OF TECHNOLOGIES

To better understand the conditions under which simultaneous NPD and OPD efforts could lead to improved product development success, it is necessary to explore the competitive nature of technologies. In either NPD or OPD, product innovations by themselves may or may not lead to improved competitive success. For example, while an individual innovation may be both highly original and creative, it may not be considered successful if it satisfies a relatively limited customer demand. An assessment of the competitive nature of products in terms of their form and function as well as their production processes is required. For this purpose, Johnson's

(1987) framework is utilized to better understand what he describes as base, key, and pacing technologies.

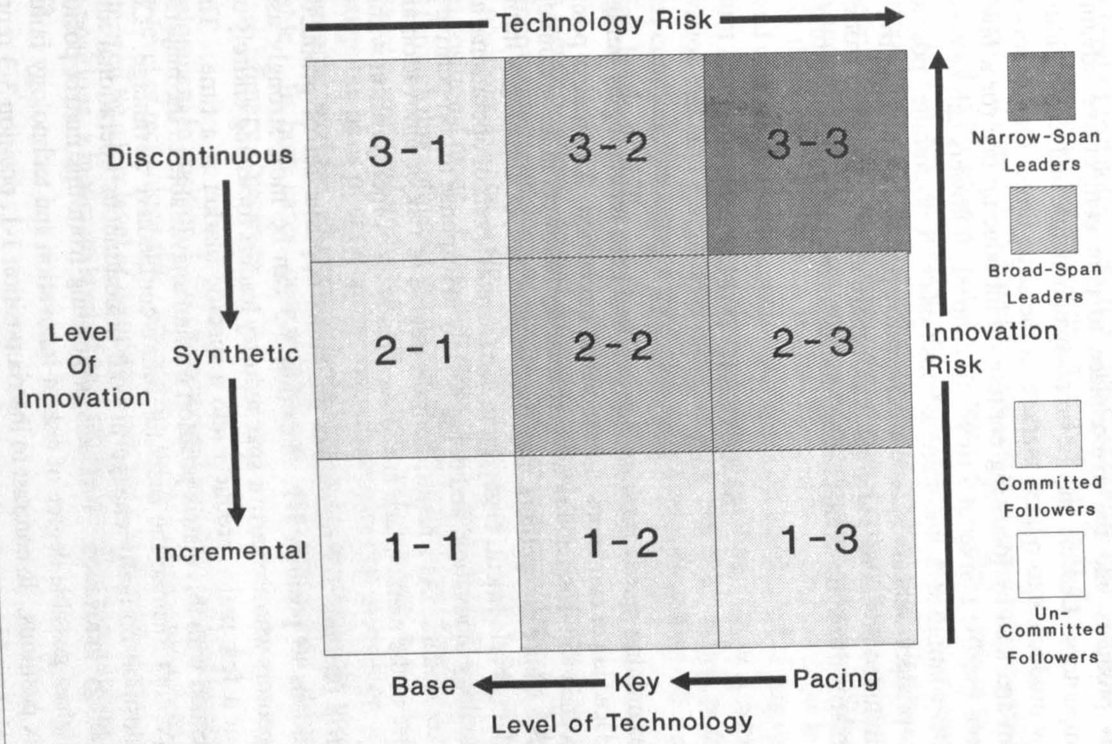
Base Technologies are common to the majority of industry competitors and their products. As such, base technologies no longer form the primary basis of competitive advantage for the firm. They are most closely associated with old product redevelopment efforts and cost leadership strategies. At the opposite end of the spectrum, *pacing technologies* are often unavailable to the majority of industry competitors. They are new technologies, currently in the earliest stages of development, with the potential to radically change the future basis of competitive advantage. Pacing technologies are most closely associated with "pure" new product development efforts and product differentiation strategies. Falling between base and pacing technologies, *key technologies* are common to a small group of industry competitors and their products, forming the immediate basis of competitive advantage for these firms.

It is interesting to note that normal product evolution eventually results in pacing technologies becoming key technologies and key technologies becoming base technologies as product and process innovations evolve from the highly unique and previously nonexistent to common and highly routine in nature. As these new, more productive and cost effective technologies emerge, they are first adopted by industry leaders and later, adopted by industry followers. This results in a technological diffusion cycle whereby leading firms will continuously attempt to push towards the next level of pacing technologies from key technologies and follower firms will push towards key technologies (often abandoned by leading firms) from base technologies.

THE RELATIONSHIP BETWEEN INNOVATION AND TECHNOLOGY

Based on the foregoing, a 3X3 matrix interaction between innovation and technology characteristics is proposed (see Figure 1). Within this framework, each of the technology categories (i.e., base, key, and pacing) represents the prevailing competitive conditions for a product or line of products associated with each of the levels of innovation (i.e., incremental, synthetic, and discontinuous). As such, the framework demonstrates that it is most likely that pacing technologies will emerge from discontinuous innovation, but progressively less likely for pacing technologies to emerge from synthetic or incremental innovation. Similarly, base technologies are generally associated with incremental innovation but may also be associated with synthetic or discontinuous levels of innovation as well.

FIGURE 1.
Product Innovation/Technology Framework:
Innovative/Positional Mode of the Firm



Also represented in Figure 1 are the ways in which we may also classify the firm as being either a leader or a follower in product innovation. Leaders introduce new products into the marketplace to gain competitive advantage over rival competitors. Leaders may be broad-span in nature and lead by introducing several new products into related markets at the same time. Or, leaders may be narrow span and lead by focussing entirely on introducing one (or a few) new products into a specific market at a time. In contrast, followers can be classified as being either committed or uncommitted positionals. Uncommitted positionals introduce new products only in response to competitive pressure from innovative market leaders. Committed positionals attempt to safeguard existing products from market leaders primarily through manufacturing process innovation and cost cutting (Johne, 1987).

STRATEGIC IMPLICATIONS

In examining *matrix position 1-1*, we find base technologies being designed and produced under conditions of incremental innovation. This matrix position is strongly associated with competitors who are industry followers in the uncommitted positional mode. These competitors may be characterized as initiating a minimum level of product development, engaging in incremental levels of operational and knowledge technology innovation, and doing so only in response to competitive pressure from market leaders. As a result, both the degree of risk of innovation and technology failure in the marketplace are lower than at any other position within the matrix.

Matrix position 3-3 represents the direct opposite set of product development conditions to position 1-1. Position 3-3 can be most strongly associated with competitors who are narrow span industry leaders focussing entirely on introducing one or a few major products into a specific market at a time. The technology associated with this matrix position is often unavailable to the majority of industry competitors forming the basis for future competitive advantage. Competitors in this position normally engage in both discontinuous operational and knowledge technology innovation. Products originating from this matrix position represent the highest possible degree of risk of innovation and technology failure among all matrix positions. In contrast to matrix position 1-1, position 3-3 represents a high level of short-term profitability risk, with the greatest long-term potential for improved profitability and competitive advantage attainable by a firm.

Examining *matrix positions 2-1 and 1-2*, we find that firms in these positions can be characterized as industry followers in the committed positional mode. These firms attempt to safeguard existing base products through synthetic innovation (i.e., operational improvements) or to safeguard key technologies through incremental innovation (i.e., overhead reduction). In both cases, cost reduction to maintain competitiveness is the primary objective. Product development in these matrix positions may be characterized by a medium level of innovation risk and a low level of technology risk (i.e., matrix position 2-1) or a low level of innovation risk and a medium level of technology risk (i.e., matrix position 1-2). In either case, a moderate level of profitability risk is tied to a medium level ROI.

Examining *matrix positions 2-2, 2-3, and 3-2,* we find that firms in these positions can be characterized as broad-span industry leaders. These firms attempt to lead by improving existing key technology products through either synthetic or discontinuous innovation or attempt to introduce pacing technology products developed through synthetic innovation. In all three cases, various combinations of product cost reduction and product differentiation may be the primary objective. Product development in these matrix positions is characterized by either medium levels of innovation and technology risk i.e., matrix position 2-2), a high level of innovation risk and medium level of technology risk (i.e., matrix position 3-2), or a medium level of innovation risk and a high level of technology risk (i.e., matrix position 2-3). All three combinations carry a moderate degree of profitability risk tied to medium to high levels of ROI.

The final two *matrix positions, 3-1 and 1-3,* represent the least likely, but not totally improbable, innovation/technology positions. Similar to matrix positions 2-1 and 1-2, firms in positions 3-1 and 1-3 may be characterized as industry followers in the committed positional mode. Firms in position 3-1 attempt to safeguard existing base products through discontinuous innovation efforts in the form of sophisticated, highly aggressive operational improvements. Firms with products in position 1-3 attempt to change the basis of competition through incremental innovation efforts and highly aggressive overhead reduction designed to make pacing technology products more affordable. In both cases, cost reduction to increase market share and profitability are primary objectives.

Product development in position 3-1 is characterized by a high level of innovation risk and a low level of technology risk. Alternately, product development in position 1-3 is characterized by a low level of innovation risk and a high level of technology risk. In both positions, a moderate level of profitability risk tied to a medium level of ROI exists.

ORGANIZATIONAL IMPLICATIONS

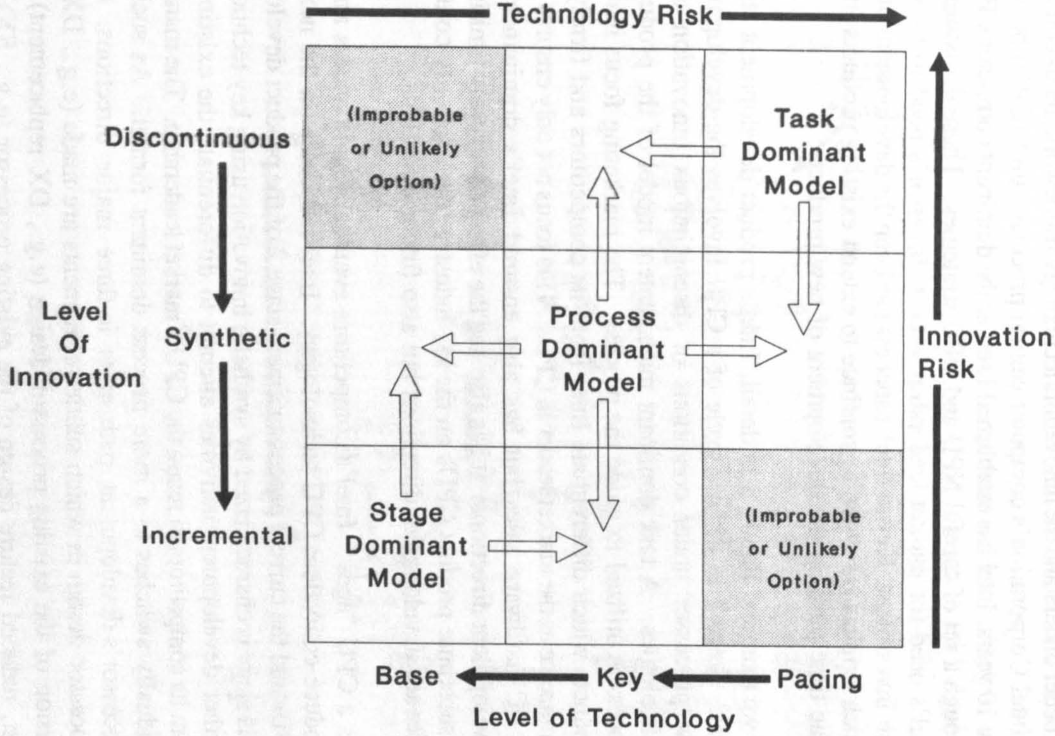
The increased emphasis on technological synergy may force many firms to reevaluate how they manage their future product development activities. In response, Shrivastava and Souder (1987) have defined a set of three technology phase transfer models (i.e., stage, process, and task-dominant models) for managing the product development process. A graphic representation of the positioning of each technology phase transfer model within the innovation/technology framework appears in Figure 2.

The first of these models is the *stage-dominant model* which is predominantly characterized by the use of strong, functionally specialized groups. In the stage-dominant model, predefined tasks are organized by function and performed in "proper functional sequence" for greater project efficiency. Product development is often defined in terms of specific functional responsibilities and boundaries. This is supported by formal technology transfer points between functions in the product development process. As such, the stage-dominant model is most ideally oriented towards the management of base technologies under conditions of incremental innovation. However, it may also prove to be effective for the management of product development for base technologies under synthetic innovation or key technologies under conditions of incremental innovation.

The second technology phase transfer model is the *process-dominant model*. In this model, functional boundaries still exist but are reduced in importance. More informal groupings of project team members as well as informal technology transfer points exist between functions. Functional involvement and activities are continually redefined. Product development is often specified in terms of the functional interaction required to complete project tasks. This model is often thought of as the compromise or transition between the stage and task-dominant models. The process dominant model can be most closely associated with the management of key technologies under conditions of incremental, synthetic, or discontinuous innovation. However, it may also be associated with base technologies under conditions of synthetic or even discontinuous innovation as well as pacing technologies under synthetic or incremental innovation.

The third technology phase transfer model is the *task-dominant model*. This model rejects all efforts to group project team members by functional area. Instead, product development activities are defined and specified in terms of optimal task execution and completion. The focus is generally on NPD effectiveness. This results in continuous overlapping and blending of NPD efforts and communications between team members. The task dominant model is most closely associated with the management of pacing technologies under discontinuous innovation. However, it may be an effective approach for managing the development of key technologies under conditions of discontinuous innovation or pacing technologies under synthetic innovation.

FIGURE 2.
Product Innovation/Technology Framework:
Technology Phase Transfer Model Positioning



AN EXAMPLE: INTEL CORPORATION CPUS

To better understand the innovation/technology framework, let us consider the example of Intel Corporation's computer central processor unit (CPU) business. Over the past 10 years, Intel has established itself as the dominant computer CPU manufacturer through a set of careful NPD and OPD strategies. These decisions have balanced Intel's need for market leadership with its investor's need to harvest value from their investment. Key to Intel's success has been the development of a clear strategy which emphasizes when to continue to extend existing products lives while at the same time pushing the development of new products.

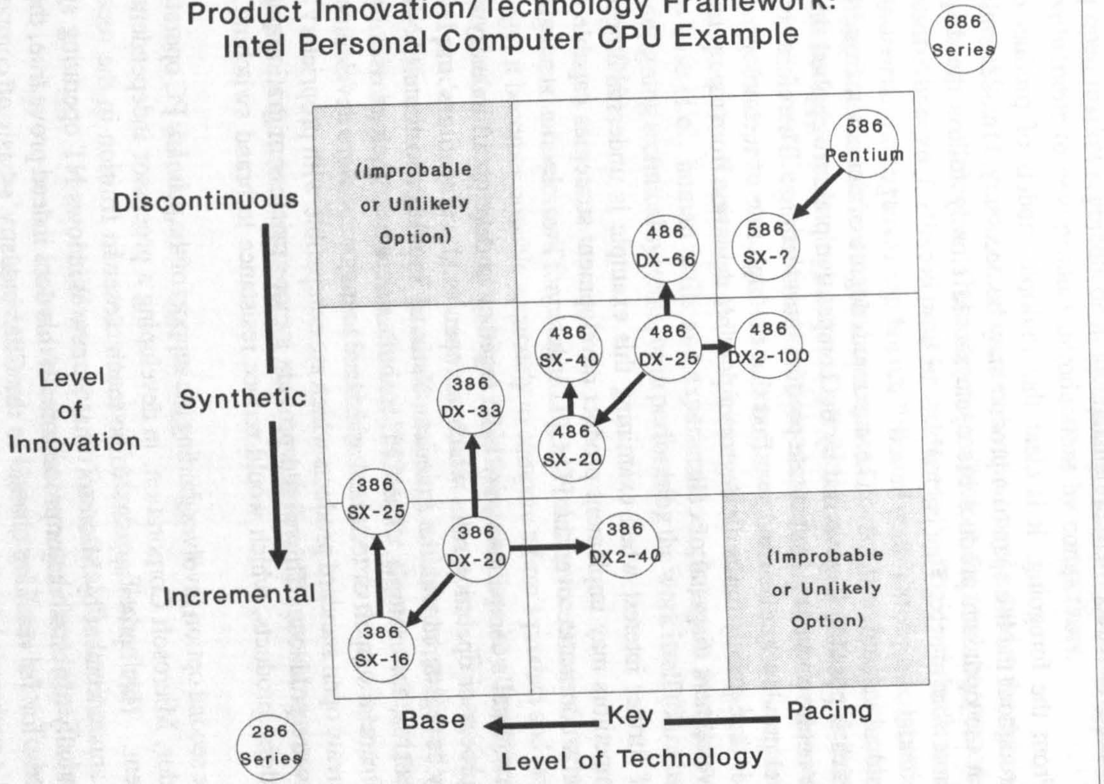
If we examine Figure 3 in detail, Intel's product development strategy becomes clear. Stage 1 in the life cycle of a CPU involves the development of a totally new processor under conditions of discontinuous innovation utilizing pacing technologies. A task dominant management model of the product development process is utilized to guide the process. The marketing focus is on creating new products which differentiate Intel from its competitors and firmly establishes its dominance as the market leader in CPUs. This focus not only ensures Intel's influence on PC hardware sales but has also ensured Intel's dominance over software development directions. It has also had the effect of severely limiting the influence of substitute product CPUs on the PC industry, thus not only controlling existing software development directions but also future directions.

As a CPU "ages," Intel's competitors eventually gain access and the ability to produce equivalent CPU technologies. Intel refocuses on the next generation of CPUs and the current processor enters stage 2 of the product development process. This stage is characterized by synthetic innovation using key technologies in which further development activities attempt to differentiate the existing product class from its competitors to retain the CPU's market leadership. The management process gradually switches to a more process dominant format. As such, the original processor's development path splits in three major directions: (1) an enhanced processor design in which subtle refinements are made (e.g., DX2); (2) a faster version of the existing processor design (e.g., DX replacement); and (3) a low cost, reduced feature design of the existing processor (e.g., SX).

In the final stage of its life cycle, the processor becomes commonplace in nature with all competitors having access to the same product and process technologies. As the next generation of CPUs is released, the processor enters stage 3 of the product development process. This stage is characterized by incremental innovation using base technologies in which further development activities attempt to harvest any and all remaining value from the product. The management process continues to evolve to a stage dominant format. As such, the CPU's development path concentrates primarily on developing faster versions of the processor. The focus

FIGURE 3.

Product Innovation/Technology Framework:
Intel Personal Computer CPU Example



of the enhancement process is to improve efficiencies until the product is no longer profitable. Finally, the product is abandoned altogether as further CPU developments continue to reduce market demand.

From the foregoing, it is clear that multiple models of product development throughout the life span of a product may be necessary. In addition, we propose that the optimum product life cycle should closely follow the diagonal of the framework matrix. That is, products are born in cell 3-3, expand to their full market potential and profitability in cell 2-2, and are managed to harvest all remaining residual value in cell 1-1. The maximum degree of deviation from this diagonal which is possible is governed by the competitive pressure applied on the firm by the nature and rate of substitute product introductions. Therefore, in the case of Intel previously discussed, we find that the high rate of technology deterioration over time greatly limits the degree of possible deviation from the optimum product development diagonal of cells.

Of further interest when examining this example is understanding how Intel's competitors may implement product development strategies capable of breaking Intel's dominance over the PC CPU industry. Two obvious strategies exist.

First, Intel's competitors may band together to develop an industry standard set of processor operation rules which are open to all competitors' use. These rules may be registered with the American National Standards Institute (ANSI) as ANSI standards, for example. The CPU manufacturers may then provide options such as financial support or technical assistance to major software development vendors to create open standard products which are compatible with proprietary Intel based software products. This would provide a more painless migration path to other vendors' products, which would reduce resistance to brand switching.

The second option involves gaining the support of the primary PC operating system vendor, Microsoft Corporation, in developing a processor independent operating system. This option appears to be much closer to fruition in the recent release and announcement by Microsoft that its new Windows NT operating system will eventually run on all major processors. If this does indeed prove true, the potential is great for far reaching change to the CPU industry's basis of competition and Intel's undisputed lead in processor development.

DISCUSSION

For the purposes of empirical verification, we propose the creation of a product innovation index which not only measures the innovativeness of a product but is also designed to measure its competitiveness. Such an index would be useful in understanding the competitive nature of existing products' successes or failures. It would also be useful for the purpose of product prepositioning in terms of identifying open market segments or in identifying areas where existing products would be vulnerable to new product introductions by competitors.

Four key dimensions of product and process innovation may be used in the evaluation of product development success. These dimensions include the machine, procedural, instrumental knowledge, and conceptual knowledge technologies of the firm. The machine and procedural technologies combine to create the firm's operational technology base and the instrumental and conceptual knowledge technologies combine to form its knowledge technology base. Operational technologies are defined as the set of instruments (i.e., machines) and procedures (i.e., production processes) used by production operators to transform component and raw material inputs into final product outputs. Knowledge technologies are defined as the firm's available knowledge base (i.e., human skills and experience) employed in inventing new products, designing technical systems, or in performing the work itself (Shrivastava and Souder, 1987).

Having developed a framework for categorizing and relating the nature of innovation to technology, it becomes possible accurately to compare a firm's product and process strengths to those of its major competitors. Utilizing the four key dimensions of product and process innovation, an innovation index is proposed. This model seeks to evaluate different competitors' products, existing in different positions within the innovation/technology matrix, in a standardized manner, thereby making it possible to "pre-position" new products more effectively in relation to those of competitors.

For purposes of future discussion we may now define the innovativeness of the firm as,

$$\text{I-Index}_f = I_{f(m)} + I_{f(p)} + I_{f(c)} + I_{f(k)}$$

where,

$I_{f(m)}$	=	Innovativeness of Machine Technology
$I_{f(p)}$	=	Innovativeness of Procedural Technology
$I_{f(c)}$	=	Innovativeness of Instrumental Knowledge Technology
$I_{f(k)}$	=	Innovativeness of Conceptual Knowledge Technology

and each $I_{f(v)}$ (f = firm 1, 2, 3, . . . , x; v = innovation variable m, p, c, or k) is a qualitative variable whose value may be equal to 1 (incremental innovation), 2 (synthetic innovation), or 3 (discontinuous innovation).

While providing a good initial basis for evaluation, further improvement to adjust for changes in the basis of competition among industry competitors is required. A technology adjustment variable, $T_{i(f(v))}$ (i = industry 1, 2, 3, . . ., y) must be added to adjust for the competitive nature of technologies where $T_{i(f(v))}$ represents a qualitative variable whose value may be equal to 1 (base technology), 2 (key technology), or 3 (pacing technology). Substituting $T_{i(f(v))}$ into I-Index$_f$ results in a revised index which may be stated as,

$$\text{I-Index}_{i(f)} = \sum I_{i(f(v))} \bullet T_{i(f(v))}$$

It is important to note that the innovativeness of the firm can not, in reality, be measured solely by internal standards. Before launching a new product, its innovation level must be measured and adjusted relative to competing firms at the same technology level within an industry. Therefore, an innovation adjustment coefficient, $a_{i(f(v))}$ is required for each innovation variable to adjust properly individual firm innovation levels relative to competitors. By this scenario, an $a_{i(f(v))} = 1.0$ indicates the innovation assessment of the firm is accurate relative to its industry competitors. In its basic form, the innovation adjustment coefficient, $a_{i(f(v)}$, may be calculated as follows,

$$a_{i(f(v))} = \frac{I_{i(f(v))\text{Actual}}}{I_{i(v))\text{Average}}}$$

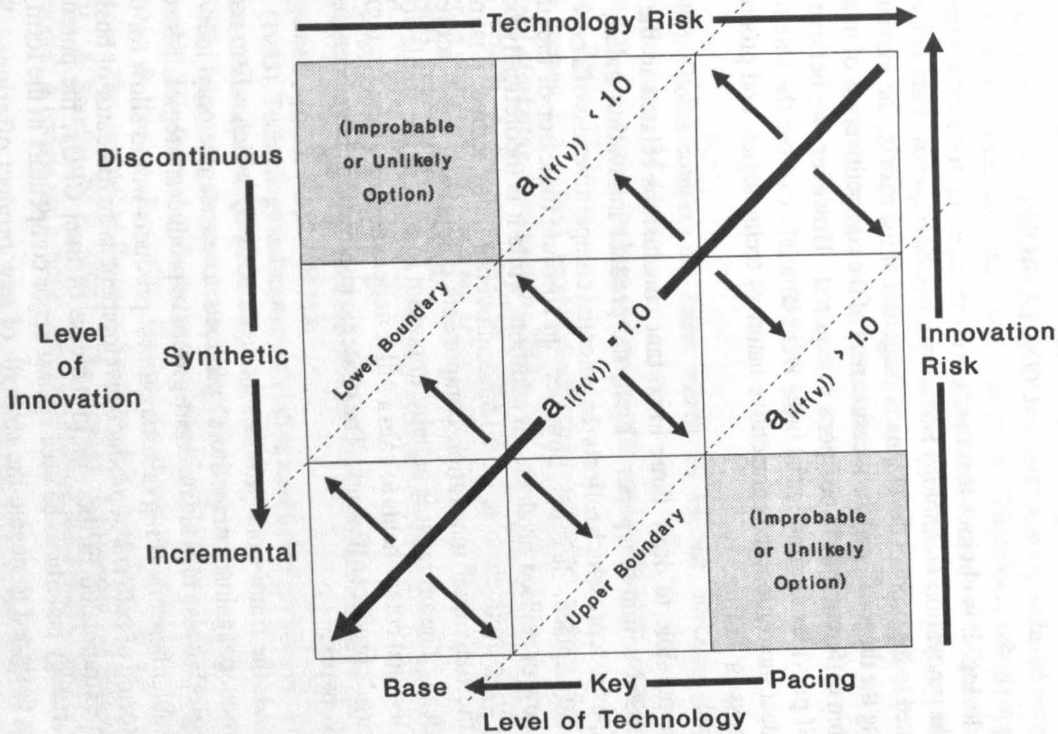
Substituting $a_{i(f(v))}$ into I-Index$_{i(f)}$, we see that the industry adjusted product innovation index, in its final form, may be expressed as,

$$\text{I-Index}_{i(f)} = \sum a_{i(f(v))} \bullet [I_{i(f(v))} \bullet T_{i(f(v))}]$$

We may further explore the behavior of the innovation adjustment coefficient, $a_{i(f(v))}$, within the product innovation/technology framework (see Figure 4). Products located within the diagonal of the matrix, extending from the upper right-hand corner to lower left-hand corner, can be said to demonstrate a balanced strategy. That is, a firm seeking to achieve: (1) a discontinuous level of innovation will utilize a pacing level of technology; (2) a synthetic level of innovation will use a key level of technology; and (3) an incremental level of innovation will use a base level of technology. Thus, in all three cases, the resulting value of $a_{i(f(v))}$ will equal 1.0.

For products located in cells to the left of the diagonal of the matrix (i.e., cells 2-1, 3-1, and 3-2) we propose that $a_{i(f(v))}$ will be less than one. This implies that the true level of innovation of these products is less than the I-Index$_{i(f)}$ would otherwise indicate. In contrast, products located in cells to the right of the diagonal of the matrix (i.e., cells 1-2, 1-3, and 2-3) will have an $a_{i(f(v))}$ value greater than 1.0. As $a_{i(f(v))}$ decreases to the left of the diagonal and increases to the right of the diagonal, lower and upper innovation boundaries are formed indicating the outer limits at which successful new product development may occur. In the case of the lower boundary, further efforts to extend old product's lives are restricted by limited innovation opportunities associated with base technologies. In the case of the upper

FIGURE 4.
Product Innovation/Technology Framework:
Behavior of Innovation Adjustment Coefficient



boundary, further efforts to extend old product's lives through the use of pacing technologies are restricted by incompatibilities between each succeeding generation of technology. In both, the economics of extending old products' lives are directly impacted by the pace at which product innovation occurs.

CONCLUSIONS

In closing, it is obvious that further research, in the form of empirical verification of the innovation/technology framework will be required. Particularly, the concepts related to the product development diagonals of the matrix, the movement of products along the diagonal, and the measurement of the competitiveness of innovations located within different matrix positions is required. However, we believe the framework itself provides a sound initial basis from which to explore the relationship between product innovation, the competitive nature of technologies, and product development success or failure.

It is possible to draw three important conclusions related to the framework as discussed within this paper. First, the product innovation index, $\text{I-Index}_{i(f)}$, is a composite score which reflects the potential competitiveness of a new product within the marketplace. It is not, however, an absolute indicator of the ultimate success of a new or revised product. In addition, while it is theoretically possible for two competing products to achieve identical overall index scores, it is much less likely that the individual innovation components comprising these scores will also be identical. Therefore, it is equally important to look at the framework positioning of individual components to gain a fuller understanding of the strategic implications of a firm's product offerings. The strategic implications have been discussed earlier in this paper.

Second, the framework provides an equal basis by which a firm may benchmark its products against competitors' products to assess not only individual product strategies but also to evaluate entire groups of product strategies. More importantly, the regular benchmarking of competitors' products would allow for the continuous monitoring of patterns of product development as an indicator of business strategy. When extrapolated further, as in the case of Intel CPUs, the potential exists for these strategy patterns to be used against major competitors in the form of "blocking" moves designed to negate the strength of new product offerings. Such blocking moves may include new or improved features, lower costs, revised marketing strategies, and other actions timed to reduce the value of competing product offerings within the marketplace.

Finally, because individual firm strategies, goals, and objectives will differ, so too will their approaches to product development. Such a view recognizes that it is possible to achieve competitive success via both new and/or old product development efforts through proper product timing and positioning. Thus, while narrow span leaders, characterized by discontinuous innovation using pacing technology, have the greatest potential to change the basis of competition among competitors as well as to capture entire portions of new markets, these same firms also face the highest levels of technological and innovation risk in today's increasingly global business environment. Alternately, firms engaged in the continuous improvement of existing products often experience significantly reduced levels of risk as well as a more immediate return on investment. Therefore, when properly positioned in relation to competing products, sustained and highly significant levels of success may be maintained by existing products for relatively long periods of time.

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