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TECHNOLOGY ENVIRONMENTS AND ORGANIZATIONAL CHOICE

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Prevailing technology conditions in an industry are predicted to influence aspects of industry structure and conduct, and corporate organization and management. This article focuses on three variables to measure industry-specific technology conditions: average development cost, development cycle, and life cycle for major new technologies. Long-cycle industries with high average development costs are predicted to exhibit higher levels of concentration and competitive stability, vertical integration, capital and research intensity, and lower rates of entry and exit than short-cycle industries with low development cost, for example. Firms in long-cycle industries are hypothesized to exhibit practices in the areas of organization, control systems, and management that differ sharply from practices in short-cycle firms. A comprehensive set of hypotheses are developed and tested regarding the influence of industry-specific technology characteristics on management and organization patterns. These hypotheses are tested using samples of thirty-four industries and thirty-nine firms. The results suggest that technology environments do influence management and organization patterns. However, within any industry, firms exhibit a range of management and organization practices. These variations appear to be linked to corporate choices regarding technology segments and market positions.

Technology has played a large role in the field of modern management theory, from the classic writings of Burns & Stalker (1961), Trist, Higgin, Murray, & Pollock (1963), Woodward (1965), Lawrence & Lorsch (1967), Perrow (1967), Thompson (1967), to the more recent work of Khandwalla (1974), and Pfeffer (1978). A primary theme in this literature describes how task-specific technologies determine the nature of work in organizations. A second theme addresses the relationship between the scope and complexity of operations technology and organizational characteristics. In addition, the stability of oper-

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ations technology has been closely linked to organizational conditions. A related area of recent research develops the linkage between technological volatility, as an external environmental condition, and management requirements (Miles, Snow, & Pfeffer 1974). All of these studies support the general principle that technology, both as it determines the nature of work in organizations and as an environmental force, strongly influences the structure and process of management. That principle underlies this research effort.

The basic thesis developed in this study proposes that market-specific technology variables strongly influence industry structure and performance, corporate organization and strategy, and managerial processes. A series of specific hypotheses about these relationships is developed and an empirical analysis is presented in this article.

The independent technology variables examined in this study are the average length of product life cycle, and the average length and cost of product development cycle by industry and firm. This study primarily assesses these variables as if they were predetermined industry-specific characteristics. Of course, individual firms can exert some control over development costs and cycles, but, it is argued, only within limits defined by industry conditions. This study focuses first on how industry-specific technology conditions influence management and organization patterns. Second, it addresses the question of organizational choice and self-determination.

Over a three-year field research period, data was collected from thirty-nine companies regarding product development cost and life cycles, as well as a number of organizational and managerial variables. These data provide the basis for examination of a number of specific hypotheses pertaining to the relationship between technology conditions and management practices.

TECHNOLOGY CYCLE ENVIRONMENTS

Firms operate in many types of technological environments. Product development and life cycles can be used to differentiate several key aspects of the technological environment. Operating conditions in industries with long development and life cycles can be expected to differ sharply from those in industries with short cycles. It is hypothesized that these differences in technological conditions will be reflected in market structure, and in corporate organization and management patterns. A set of hypothesized conditions will first be developed for firms in industries which typically exhibit long development and life cycles, and high development costs.

Long-Cycle Environments

Industries characterized by high development costs and long development and life cycles might be expected to exhibit a number of pervasive characteristics. Product development activities in such industries are often concentrated in a few large and highly expensive projects. The aerospace, jet engine, pharmaceutical, and nuclear power industries typically experience ten to fifteen year development periods, with correspondingly long periods of market acceptance. In such industries, the cost of developing a major new technology can exceed one billion dollars. These technological and financial realities contribute to a number of organizational characteristics typically found in firms in such industries.

Due to the expense of development in such industries, new projects are not initiated casually. Extensive review, approval, and concurrence procedures are established to ensure complete analysis of any proposal. Given the investment stakes, such firms exhibit a very low tolerance for failure. They proceed only when a very high probability of success can be predetermined. Such firms' activities may be consistent with the "Analyzer" mode described by Miles and Snow (1978). Such evaluation procedures, of course, contribute to the length of development periods found in such industries. Firms in such industries generate extensive documentation for internal review, and conduct numerous trials of component and systems technology to ensure feasibility, security, and market acceptance. Internal reviews and tests, in addition to public regulation, and technological scope and complexity, contribute to the long development cycles in such industries.

It can be hypothesized that the nature of management in such firms bears identifiable characteristics that can be linked to technological conditions. A very low rate of management turnover can be anticipated in long cycle firms. Such firms will find it desirable to retain managers through the duration of the cycle in order to ensure technological and managerial continuity. Compensation systems in firms in long-cycle environments will emphasize long-term benefits and rewards. These firms will invest heavily in employee training and development, as a corollary of long-term employment practices. In addition, the variable component of compensation, at least as related to individual performance, will be relatively low in such firms. Long cycle firms may not wish to encourage individual heroics.

The length, scale, and complexity of the development cycle requires highly structured management systems. Individual management positions in such firms will tend to be defined in very narrow, specific, and technical terms. Individual managers will have a narrow span of functional command, with responsibility for only a discrete area of activity. In development projects, specific assignments may be defined by "PERT" program management techniques. Performance of a specific assignment or function in the prescribed manner will be the primary focus for individual managers. Individual creativity and initiative may in fact be discouraged in such situations.

Industry Structure and Performance

Competition in such industries may also exhibit fairly orderly patterns, with occasional turbulence during transition periods to new technologies (Sultan 1975). Industries with long development and life cycles and high development costs can be hypothesized to be more concentrated and stable than other industries, due to technology and scale-based barriers to entry. The development cycle and cost both present formidable barriers to entry, and entrenched competitors will have ample time and warning to prepare for new entrants. In addition to a high degree of concentration, a high degree of stability in industry competition might be expected. Market share positions would not change frequently or abruptly. Entry or exit would occur with low frequency.

Such industries may exhibit other oligopolistic characteristics, including limited price competition, follow-the-leader behavior, and various forms of risk and market-sharing (Scherer 1970). Financial performance in such industries may reflect the superior returns often found in such markets.

It can also be hypothesized that in addition to exhibiting a fairly high level of research spending, such industries will exhibit relatively high levels of capital intensity. Capital intensity could result from the high levels of vertical integration often found in such industries. Firms in these industries would find it useful to integrate vertically to ensure quality, security, and control of key supplies. With long product life cycles, capacity retooling and flexibility needs would be limited, supporting vertical integration. Cost of supply might not be a pressing issue in such industries, given limited price competition. Vertical integration also promotes stability in the industry, and provides another barrier to entry.

As in all oligopolistic industries, individual managerial initiative will be forcibly discouraged. When individual managers cut prices, introduce new products, services, marketing tactics, or any other competitive innovation, these initiatives can contribute to industry instability. The price war phenomenon applies not only to pricing, but any other form of competitive activity, including product or process innovation (Sultan 1975). Consequently, tight controls over managerial activities can be expected. Firms in such industries can be hypothesized to contain extensive, formal information and control systems.

The Short-Cycle Environment

Firms in industries characterized by short development and life cycles face an entirely different set of concerns. If the average new product development cost is also relatively low, technological barriers to entry will be minimal. Such industrial environments will be highly turbulent, with frequent entry and exit of participants. New entrants accelerate the pace of technological obsolescence and raise the potential for severe technological and price competition.

Technological and competitive conditions in such industries dictate an entirely different set of organizational and managerial approaches. Where firms in long-cycle environments pursue a few carefully screened and selected large-scale projects, firms in the short-cycle setting may pursue a number of smaller projects. Short-cycle firms do not have the luxury of carefully reviewing and analyzing potential projects. In industries with average development cycles of twelve months and life cycles of twenty-four months or less, an extensive twelve-month project review would double the development cycle and dangerously reduce the window of market acceptance for the product. As a result, firms in such industries may opt to let the market screen their projects for them by introducing a number of new products, with the expectation that only a few will survive. Short-cycle firms will exhibit a higher tolerance for failure than long-cycle firms. They may exhibit characteristics associated with the "Prospector" mode cited by Miles & Snow (1978).

In contrast to long-cycle firms, success in short-cycle industries depends upon the initiative and innovation of individual managers. Firms in such industries may display less stringent controls over line managers. Where management in long-cycle firms emphasizes highly specialized and narrow job descriptions, short-cycle firms may exhibit broad, multifunctional managerial positions, with extensive spans of control. Such an approach reduces decision time and permits greater agility in responding to a more dynamic environment. These firms may exhibit "high velocity" management characteristics, emphasizing unstructured decision processes (Mintzberg 1973; Quinn 1978).

Management continuity will be less valuable in a short-cycle environment. In any environment, market conditions can change dramatically from cycle to cycle. The technological, competitive, and marketing foundations of one cycle will be replaced by a new set of realities. Management assumptions and styles that are appropriate for one cycle may be inappropriate in the next. In many cases, a replacement of management can be valuable to the organization as cycles change, especially if there are significant discontinuities in market, technology, and competitive conditions. In many short-cycle environments, a high rate of management turnover may be dictated by changing industry conditions.

Such management realities dictate different compensation practices as well. Long-cycle firms emphasize long-term, fixed compensation in order to promote managerial continuity and discipline. Variable compensation in long-cycle firms will be based primarily on corporate, not individual, performance. Corporate performance in such firms does not rest upon individual heroics. These firms will offer substantial long-term benefits, with lengthy vesting periods. Compensation schemes of this sort are wholly inappropriate in short-cycle environments. In such industries, corporate performance depends a great deal on individual heroics in the short term. Compensation should emphasize short-term, variable, and individual performance considerations.

Organization structures are also likely to differ for firms in different technological environments. In long-cycle firms, functional management structures may dominate the organization. The organization itself will tend to be very hierarchical, with many layers of management. Large staff units will be required to oversee project review activities, to manage integration mechanisms between functional divisions, and to administer complex planning and control systems. General Electric, with its primary focus on long-cycle industries such as jet engines, power systems, locomotives, medical and nuclear technology, exhibits many of these characteristics. Notably, GE has recently sold a series of businesses with short-cycle qualities, including its small appliance, consumer electronics, and semiconductor units. In 1987, GE reduced the number of profit centers in its organization from almost three hundred to under forty, and initiated an extensive new organization emphasizing functionally-focused units and management positions. In contrast, short-cycle firms will exhibit more general managers, more profit centers, more divisional independence, smaller staffs, and fewer layers of management. Short-cycle firms may be more likely to exhibit "dynamic network" characteristics (Miles & Snow 1986).

Management style and process will also vary sharply. Long-cycle managers will tend to be technical, scientific, professional, and often bureaucratic. Management in such settings is highly rational and systematic, and practiced according to a standardized set of procedures (Frederickson & Mitchell 1984). In contrast, an effective short-cycle manager might exhibit a more intuitive management style. Personality, energy, and leadership skills would be useful qualities for the short-cycle manager. Such traits would be less valuable, and some even potentially damaging, to the long-cycle manager. The left brain-right brain distinction (Sperry 1968; Mintzberg 1976; Buzan 1983) may also be relevant in contrasting managerial requirements in these two settings. The leader-manager literature (Zalesnik 1978; Bennis & Nanus 1985) could also be relevant.

Short-cycle industries are likely to be less concentrated than long-cycle industries. They also will exhibit less stability, as vendors enter and exit the industry. Market share rankings, which may remain virtually fixed for a decade or more in long-cycle industries, will exhibit high volatility and turnover in short-cycle industries. Short-cycle conditions will dictate strategies that emphasize the use of external suppliers, and it can be hypothesized that vertical integration and capital intensity will be limited in short-cycle industries. Such industries are also unlikely to be research-intensive. R&D expenditures will be devoted almost entirely to applied development and not basic research. Such industries will secure any underlying scientific research from outside sources.

The financial performance of short-cycle firms will exhibit much greater volatility than their long-cycle counterparts. Short-cycle industries as a whole may generate high returns on investment because of low capital-intensity. However, it can be hypothesized that average returns will be lower and more volatile for short-cycle industries because of technological and competitive conditions.

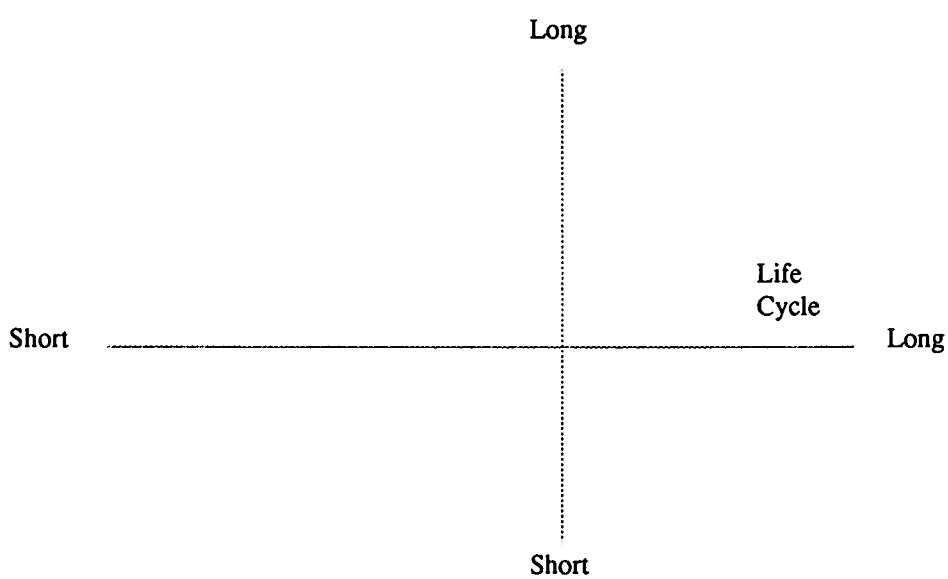
Other Environments

A two-dimensional view of technological environments appears in Figure 1. The short- and long-cycle environments have been discussed; the other two environments in this figure may also exhibit distinctive characteristics.

The long development, short life cycle environment presents a difficult set of conditions, particularly when average development costs are high. Industries such as semiconductors, disk drives, instruments, and factory automation systems have found themselves in this setting in recent years, and poor financial performance can be expected to result. While such conditions might be expected to be transitory, often following major technological breakthroughs, it is possible that an industry may remain in this state for an extended period of time. A particularly aggressive competitor can force a market into this zone in order to initiate consolidation of the industry, for example.

Customers in such industries are typically eager adopters of new technology. Industries that serve the scientific and engineering communities might exhibit long development and short life cycle characteristics. Industries that serve customers who themselves operate in

FIGURE 1.
Development Cycle



short-cycle environments may also fall into this category. Whatever the cause, firms in such industries face a difficult challenge. The cost and risk of development are high, and the potential rewards are low. Financial performance in such industries can be hypothesized to be poor.

Despite poor financial performance, new entrants may appear frequently with newer and better technologies. The primary barriers to entry in such industries are technological, and new entrants with superior technology will find it easy to penetrate the market. Exit from the industry may also be frequent.

Such industries are likely to exhibit a high level of research intensity. Basic scientific research and state-of-the-art development are important success factors in such industries. Firms in such industries could be expected to emphasize technological entrepreneurship. Entrepreneurial management will be needed, as in short-cycle environments, but technical skill and knowledge may be more important in this type of industry. Close contacts with customers, and codevelopment with customers, may be successful strategies in such industries, as firms attempt to mediate the effects of technological change on their market positions.

Such firms will likely be staffed by younger, technically competent managers. Corporate cultures that emphasize technical competence and virtuosity might be common in such industries. Compensation practices would presumably emphasize short-term, individual contributions. Individual and small team heroics are very important in such settings. Quite often, a single individual could be critical to a firm's market position. Organizational characteristics might reflect the importance and personality of such individuals. At the same time, management turnover is likely to be high.

While technological standing ultimately determines corporate performance in this setting, the reverse is true in the lower right-hand corner of Figure 1. In short development and long life cycle environments, technological variables do not determine market position. In such industries, product life is somehow extended, and technological change is not rapidly transmitted to the customer. This pattern may be due to slow customer acceptance of new products, or the vendors' ability to extend markets for existing products. Strong marketing, product differentiation, and distribution are primary vehicles for extending product life in the face of newer technologies. Companies with strong brands, strong distribution or sales and service organizations, and high quality, low cost products dominate industries in this quadrant. While such industries are relatively rare, the appliance, telephone, and many consumer goods industries exhibit such characteristics.

Each of the four environments in Figure 1 can also vary according to the average development cost associated with introducing a significant new product in a given industry. Taking this factor into account, a detailed presentation of the hypotheses discussed above appears in Figure 2. We will examine a number of these hypotheses.

RESEARCH DESIGN

In order to partially examine how technological conditions influence industry and corporate realities, a field research effort was undertaken. Thirty-nine firms cooperated in the study by agreeing to provide data on development cycle and cost and life cycle data for all major new products introduced between 1960 and 1985. These responding firms were

FIGURE 2.
A Technology-based Theory of Management

ENVIRONMENT	A1. Long Development Cycle, Long Life Cycle, High Development Cost	B1. Short Development Cycle, Short Life Cycle, Low Development Cost	C1. Long Development Cycle, Short Life Cycle, High Development Cost	D1. Short Development Cycle, Long Life Cycle, High Development Cost
Industry Structure and Performance				
Concentration	High	Low	Medium	High
Entry/Exit	Low	High	Medium	Medium
Stability	High	Low	Low	Medium
R-Intensity	High	Low	High	Low
K-Intensity	High	Low	Medium	High
V-Integration	High	Low	Medium	High
ROI	High	Medium	Low	High
Competitive Conditions	Stable	Volatile	Volatile	Potentially Unstable
Corporate Organization				
Policy Forums	Closed	Open	Open	Closed
Power	Monolithic	Diverse	Diverse	Monolithic
MIS	Extensive	Limited	Medium	Extensive
Authority	Strong	Ambiguous	Ambiguous	Strong
Staff	Large	Limited	Medium	Large
Layers	Many	Few	Few	Many
Controls		Weak	Selected	Selected
Compensation	Fixed., LT	Variable, ST	Variable	Long-Term
Divisional Format	Functional	Profit Centers	Many	Functional
Decision Process	Structured	Freestyle	Freestyle Technical	Structured
Corporate Strategy				
Market Thrust	Focused	Diffuse	Tech-driven	Focused
Pricing	High Margin	High Margin	Premium	Premium
Product Line	Narrow	Broad	Diverse	Stable
Promotion	Targeted	Mass	Limited	Extensive
Sourcing	Internal	External	External,r	Internal
Manufacturing	Integrated	F.A.T.	Technology	Critical
Critical Success Factors	Focus, Quality, Scale, Coordination, Scope Systems	Agility, Speed, Monitoring, Responsiveness, Change	Customer ties, Speed, Team Work	Branding, Distribution, Scale, Quality
Management				
Span of Control	Narrow	Wide	Narrow	Narrow
Functional/General	Functional	General	Technocrat	Functional
Decision Process	Professional	Intuitive	Intuitive	Professional
Turnover	Low	High	Low	Low
Career Path	Predictable	Volatile	Open	Vertical,RLow,
Entry Point, Type	Low, Common	Diverse	Common	Common
Work Contract	Extended	Discrete	Equity	Extended
Style	Administrative	Entrepreneurial	Venture	Professional

chosen to provide coverage of a number of different industries while providing in-depth coverage of several industries. From the lists of all new product introductions identified with these firms, products were selected that represented significant commercial and technical advances, according to industry experts.

With the resulting 413 product innovations, it was possible to classify individual industries according to average development and life cycle and cost. Life cycles are measured here as the period from general commercial introduction to peak unit sales, based on monthly shipment levels. This data was relatively straightforward to capture. Development cycles were more difficult. The development cycle was measured as the period from formal project approval to commercial introduction. In many firms, formal mechanisms exist for reviewing and budgeting new projects. In these cases, formal development was assumed to have commenced when the project was awarded a development budget. In other cases, the predevelopment and development periods blur together. Variances in development practices across corporations and industries cause concern about the measurement of development cycles.

Where possible, we looked for evidence of formal management review and approval of the project, and explicit allocation of resources to the undertaking. The goal here was to identify the formal development period, not to measure the predevelopment period or the

FIGURE 3.
A Conceptual View of the Development Process

(1) Pre-Development	(2) Review/Concurrence/ Approval	(3) Formal Development	(4) Pre-Commercialization	(5) Commercialization
(1) AUTONOMOUS ACTIVITY				
(2) Preperation and presentation of formal plan		(3) Accounting Initiated	(4) Prototype Alpha, Beta Sites	(5) Market Dev. Promotion
(1) BOOT-LEGGING				
(2) Formal horizontal and vertical process		(3) Resource Commitment	(4) Process Development	(5) Distribution
(1) NO FORMAL FUNDING				
		(3) Formal funding and staffing	(4) Market Plan Development	(5) Sales
(1) NO FORMAL REVIEWS				
(2) Initial Visibility		(3) Systematic development	(4) Organization and staffing	
(1) BASE FEASIBILITY TESTS				
		(3) Regular Management Reviews	(4) Ramp up Capacity	(5) Organizational Responsibility Defined

review period. The pre-commercialization period, or the time from prototype to market introduction, was included as part of the development cycle. It proved to be difficult to measure the predevelopment and review periods accurately, although it was possible to gain some general insights into these phases of activity.

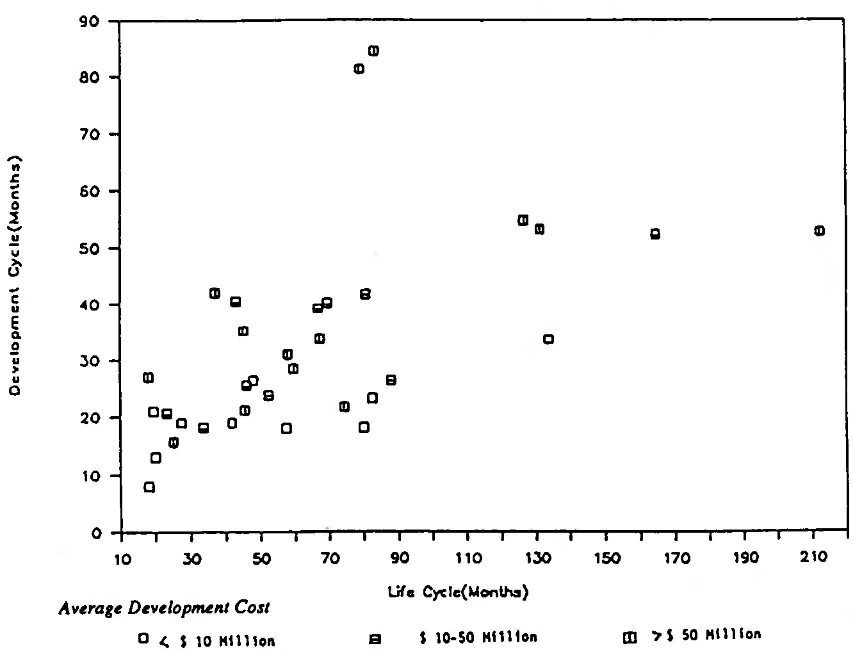
The primary independent variables used in this study measure the period of time from commencement of a formal development project until general commercial availability of the new product, and from initial commercial availability until peak unit sales. The latter was defined as the first month in the first year in which unit sales irreversibly declined.

Development costs were defined as all expenses allocated to the project during the development cycle. These three variables were measured for each of 413 new products. It was then possible to measure average development cycle and cost, and life cycle by firm and industry. The relationships between these technological factors, and industry structure and performance, corporate strategy, organization and management characteristics can then be examined in specific detail.

Inter-Industry Patterns

The 413 new products included in this study were grouped into thirty-four three and four digit SIC industry sets. These industries vary in terms of the precision of definition. Many are defined in fairly broad terms; others reflect very specific product lines. Significant differences in average development and life cycles appear in this sample, as seen in Table 1.

TABLE 1
Average Product Development and Life
Cycle Patterns for 34 Industries (1960–1985)



The average development cycle for the 413 innovations included in this study stood at 30.45 months. The average product life cycle, from general commercial availability to peak unit sales, totaled 65.1 months. Actual industry observations exhibit a range of average development cycles from ten to 84.5 months; and life cycles from eighteen to 212 months. Averages for each of the industries appear in Table 1.

These observations were then classified into four categories, based on their position in the table. Industries with average development cycles below thirty months and life cycles below sixty months were classified as short-cycle environments. Industries with averages above thirty and sixty months were classified as long-cycle environments.

The symbol used for each industry observation reflects the average development cost for new products in that industry. Overall, average development costs are highest in long-cycle environments, and lowest in industries with short development and long life cycles (Table 2).

Data on each of the industries represented here were gathered from the Census of Manufacturers. Selected variables were then aggregated for industries in each quadrant. As Table 2 shows, there is significant variance across quadrants in a number of these characteristics. Profitability as a percentage of sales is lowest in the long development/short life cycle quadrant, as predicted. Perhaps surprisingly, the short cycle environment exhibits higher profitability than the short development/long life cycle quadrant.

The total asset-to-sales ratios in the four quadrants are not entirely consistent with expectations. The long-cycle environment has a relatively low ratio. However, the long cycle quadrant exhibits the highest fixed asset ratio, indicating higher capital intensity in manufacturing. R&D spending is lowest for the short/long quadrant, further reinforcing the point that technological innovation does not play a critical role in such environments. Contrary to expectations, R&D spending is highest in short cycle industries. Concentration ratios do not differ significantly across the four quadrants.

Initial examination of industry characteristics provides limited indication that systematic differences exist in these four quadrants. More detailed statistical analysis of this sample suggests that significant differences exist among the populations of the four quadrants.

Statistical Analysis

ANOVA and MANOVA techniques were used to determine whether significant differences exist in the quadrant populations presented in Table 3. These techniques permit examination of how variances in development and life cycles correlate with industry characteristics.

In order to test the separate effects of these two variables, the samples in quadrants I and II, the short life cycle population, and those in quadrants III and IV, the long life cycle subset, were contrasted so as to consider the pure influence of the life cycle variable (see Figure 2 for quadrant definitions). Similarly, we pooled the samples in quadrants II and III, the long development cycle subset; and I and IV, the short-cycle subset to consider the pure influence of development cycle. These results appear in Table 3. The analysis indicates that:

a. The ratios of "cost of goods/sales," "GS&A/sales," "fixed assets/sales," and "sales per employee" are significant in contrasting the short and long life cycle population;

TABLE 2
Selected Industry Characteristics
(By Quadrant)
1977–1982 Averages

Quadrant Conditions (Development/ life cycles)	*Development/Life Cycle* Short/ long	Long	Long/ short	Short
Length of development cycle (months)	22.33	51.59	37.17	20.27
Average development cost ($ mill)	3.15	6.51	8.33	3.37
Length of life cycle (months)	81.21	110.53	45.87	35.75
Number of industries (count)	4	11	4	15
Net profit/sales (%)	3.50	2.67	2.40	3.71
Gross margin/sales	31.53	28.31	35.08	35.39
Total assets/sales	.66	.60	.61	.55
Net fixed assets/sales	.08	.12	.09	.10
Average annual wage ($/hour)	10.15	12.39	10.90	11.24
Concentration ratio ($/firm)	37.53	36.38	36.90	36.54
R&D/sales (%)	.60	1.70	1.80	2.60

Source: *Census of Manufacturers*, 1977–1982.
Notes: Data for each of the thirty-four three- or four-digit SIC industries were compiled and averaged for each of the four quadrants. An industry was classified into a quadrant based on the average development and life cycle statistics for products in that industry.

b. The ratios of "cost of goods/sales," "fixed assets/sales," and "advertising/sales" are significant in contrasting development cycle populations;

c. Since the hypotheses about life cycle are more strongly supported (four F-ratios at level $p < 0.95$) and the hypotheses about development cycle are less strongly supported, the results are consistent with the conclusion that the life cycle variable has more influence than the development cycle.

The next level of analysis attempts to identify interactions between life and development cycle patterns. As a contrast to ANOVA, the multivariate two-way MANOVA allows for analysis of the responses at each combination of factor levels. The effects of interaction between development and life cycles on each quadrant population will be reviewed using MANOVA. The calculation formulas for MANOVA used here require the same size sample in each category. Although the sample in this analysis is small, meaningful results can be generated by the use of reduced and extended samples techniques.

Results for the Reduced Sample

The reduced sample is defined by choosing four subsamples of n observations in quadrants I and III at random, plus the full samples (n) of quadrant II and IV, the smallest populations, in order to equalize population size in all quadrants. There could be numerous combinations for the reduced sample solution. All of the results show that the interaction of the development and life cycle is quite strong, as seen in Table 4. The significance of the F-ratios increases significantly when the interactions of life and development cycles are examined in MANOVA analysis.

The extended sample solution is created by repeating samples in quadrants II, III, and IV, until all the quadrants have fifteen samples and the results are shown in the second set of columns of Table 4.

a. The ratios of "profit after tax/sales," "inventory/sales," "total assets/sales," "total equity/sales," "sales per employee," "capital expenditure/sales," "advertising/sales," and "income/sales" vary significantly with respect to average development cycles;

b. The ratios of "cost of goods/sales," "GS&A/sales," "fixed assets/sales," and "sales per employee" are significant and are strictly consistent with previous results. As in

TABLE 3
One-Way ANOVA
(By Pooled Cycle)

Sample Populations Ratios	*For life cycle (1+2 & 3+4) One-way ANOVA F-Ratio*	*For development cycle (1+4 & 2+3) One-way ANOVA F-Ratio*
Cost of goods/sales	7.050**	2.354*
GS&A/sales	6.034**	1.864
Profit after tax/sales	0.087	0.530
Inventory/sales	0.052	1.190
Fixed assets/sales	4.970**	3.821**
Total assets/sales	0.348	0.054
Total equity/sales	0.020	0.180
Capital Expenditures/sales	0.053	0.520
Sales per Employee	4.361**	1.095
R&D/sales	0.286	0.097
Advertising/sales	1.399	2.390*
Income/sales	0.087	0.530
Income/assets	0.318	1.439
Income/equity	0.009	0.740

Notes: *(p)significance < .10
**(p)significance < .05
***(p)significance < 0.01

	$F_{0.10} = 2.88$	$F_{0.10} = 2.14$
	$F_{0.05} = 4.17$	$F_{0.05} = 2.69$
	$F_{0.01} = 7.56$	$F_{0.01} = 4.02$

FIGURE 4.
A Conceptual View of Development and Life Cycle Patterns

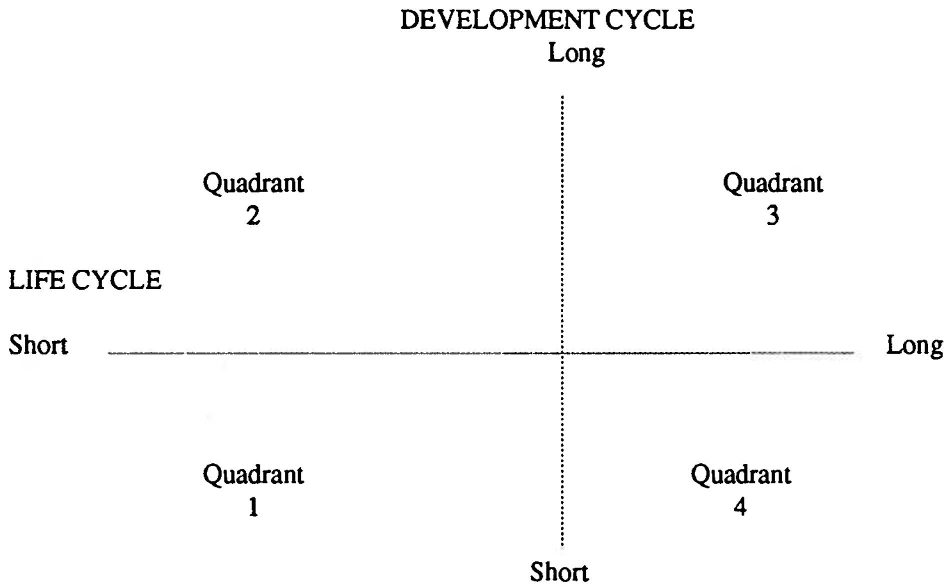


Table 3, product life cycle length is strongly related to patterns for these financial variables;

c. The ratios of "inventory/sales," "fixed assets/sales," and "advertising/sales" are significant in the final column of Table 4. Twelve out of fourteen ratios are significant in at least one row of Table 4. The financial ratios that are not found to vary significantly are "R&D/sales" and "income/equity." This finding implies that cycle characteristics may influence the structure of an industry or firm more than its profit performance, and that R&D spending levels represent a variable subject to managerial choice regardless of external conditions.

This analysis has been conducted at the level of interindustry comparisons. The results suggest that product development and life cycles do exhibit a significant relationship with certain industry characteristics. However, the results are by no means conclusive, particularly for the first-order analysis. A second analytical perspective appears warranted. It is important to go beyond interindustry analysis to examine how development and life cycle patterns correlate with the characteristics of individual firms.

COMPANY SPECIFIC ANALYSIS

To examine more precisely how operating conditions vary across technology environments, characteristics of the firms in this study were analyzed independent of their principal industry. Firms were classified into the four quadrants based on their firm-specific develop-

TABLE 4
Two-Way ANOVA
(Interaction)

F-Ratios	*For Reduced Samples*			*For Extended Samples*		
Items	*dev. cycle*	*life cycle*	*inter-action*	*dev. cycle*	*life cycle*	*inter-action*
Cost of goods/sales	0.21	0.01	0.33	0.27	9.56***	0.36
GS&A/sales	1.21	1.36	2.40*	0.05	10.19***	0.30
Profit after tax/sales	0.06	0.01	2.34*	3.99***	0.01	0.93
Inventory/sales	0.30	1.61	0.90	3.10**	0.18	3.37**
Fixed assets/sales	0.89	0.44	0.10	0.05	4.48***	3.46**
Total assets/sales	0.00	0.07	2.86*	5.78***	0.40	0.25
Total equity/sales	0.14	0.32	3.37**	3.06**	0.16	1.03
Capital Expend/sales	0.50	0.54	1.00	3.98***	0.69	0.74
Sales per Employee	0.38	0.78	3.51**	0.89	7.88***	.21
R&D/sales	0.55	0.40	1.50	0.31	1.29	0.61
Advertising/sales	3.83**	3.47**	5.84***	1.97	1.75	3.64**
Income/sales	1.06	1.01	2.34*	3.99***	1.01	1.93
Income/assets	0.05	0.00	0.62	0.34	0.00	2.04*
Income/equity	0.11	0.00	0.29	1.00	0.42	1.51

Notes: *(p)significance < .10
**(p)significance < .05
***(p)significance < 0.01

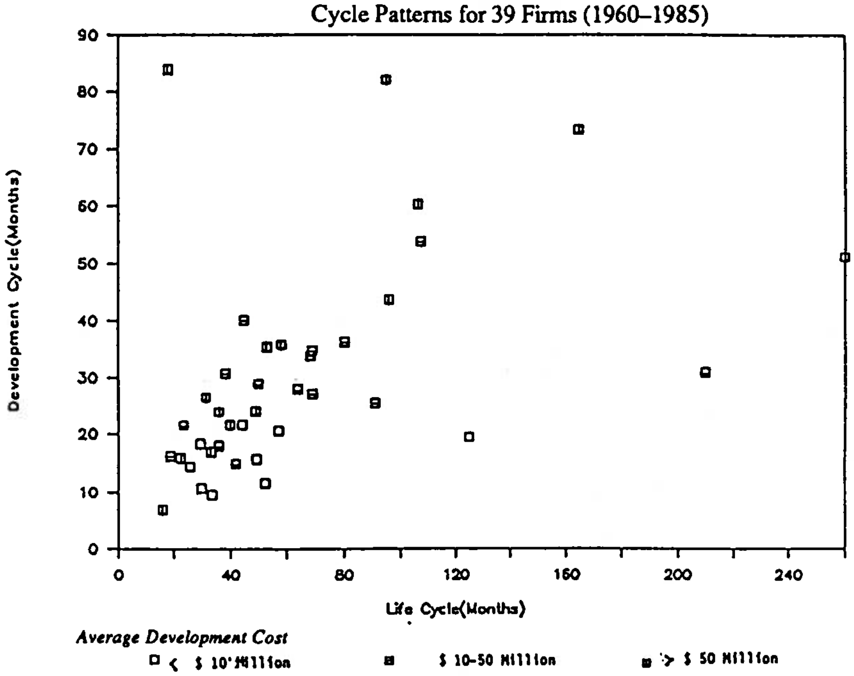
F0.10 = 2.23 F0.01 = 3.65
F0.05 = 3.01 F0.05 = 2.04
F0.01 = 4.77 F0.01 = 3.65

ment and life cycle averages, *regardless of their principal industry*. A scatter diagram for the firms appears in Figure 5.

Characteristics of the firms in each of the four quadrants were then averaged and compared to determine if significant differences could be observed. As Table 5 indicates, it is possible to identify a number of instances in which company characteristics differ. Long-cycle firms tend to be significantly more capital-intensive, as indicated by higher asset to sales ratios. Long-cycle firms also dedicate more than twice as large a percentage of annual sales to capital expenditures. They also spend much more on research and development in contrast to short-cycle firms. General sales and administrative expenses as a percent of sales are also highest for long-cycle firms.

The data in Table 5 indicate significant operating differences in short/long- and long/short-cycle firms as well. Firms with long development and short life cycles tend to be less capital intensive than other firms. They also spend far less on general, sales, and administrative activities, and virtually nothing on advertising. They carry far less inventory as well. These firms seem to focus on minimizing their asset base. Capital expenditures are extremely low for this group of firms. Asset minimization partially compensates for the relatively low gross margins and returns on sales that characterize such industries.

FIGURE 5.
Average Product Development and Life
Cycle Patterns for 39 Firms (1960–1985)



Firms in industries with short development cycles and long life cycles seemingly enjoy ideal operating conditions. However, it is clear that factors other than technology determine success in such markets. In such industries, brand differentiation, distribution, cost position, or other factors will determine market success. This sample of firms exhibits a relatively low gross margin, suggesting the possible importance of high volume-low margin operations in such industries. The high capital intensity and capital spending exhibited by these firms further suggest the role played by economies of scale in operations. Such industries also exhibit high current asset ratios, indicating the importance of customer terms and service. Firms in such industries also exhibit the highest level of advertising activity. They do not spend heavily on research and development, however. If technology were a critical competitive factor in such industries, the average life cycle would be considerably shorter. The fact that life cycles average more than twice the length of development cycle in such industries indicates that technological innovation does not drive market conditions.

These summary statistics support several of the hypotheses developed earlier. In general, firms that operate in longer cycle environments tend to exhibit greater capital intensity and capital spending rates. Such firms also tend to spend a significantly larger percentage of their sales on research and development. Firms operating with long development and life cycles also exhibit the highest management overhead, as measured by General, Sales, and Administrative expenditures. These patterns are generally consistent with the relationships hypothesized in Figure 2. There appears to be a linkage between the technological realities facing a firm and its operating practices.

Why is it that analysis of individual firms tends to support these hypotheses more closely than analysis of industry data? In examining company-specific data, it becomes clear that individual firms do not always occupy the same quadrant as their principal industry. This was true for almost one-third of the companies in this sample. This pattern was linked of course, to the diversity of many of the firms. In addition, however, it became clear that significant variances in corporate development cycle, cost, and life cycle existed within narrowly defined industries. This pattern appears to be highly consistent with the proposition that a mix of competitive strategies exist within any industry (Miles & Snow 1986).

Intra-Industry Comparisons

It may be useful to examine cycle and operating characteristics for different firms within the context of a single industry. In any given industry, regardless of average cycle lengths, firms will be dispersed around the mean cycle times. For example, in the tire industry subset of this sample, the average development cycle was 30.9 months, and the product life cycle averaged 71.1 months. Using these averages to define a grid specific to this industry, it is possible to examine the relative positions of individual companies within that grid. Those positions can then be examined to determine if they can be linked to differences in strategy, organization, and management.

TABLE 5
Industry Characteristics and Cycle Conditions Company Data for Thirty-nine Firms, Aggregated by Quadrants for the Principal Industry of the Firm

	Industry Environment			
*Variable**	*Short*	*Long*	*Short devl Long Life*	*Long devl Short Life*
Number of firms	11	13	4	11
Development cycle	17.25	46.67	20.90	32.76
Development cost	4.90	27.53	2.14	24.54
Life cycle	25.79	101.55	69.38	39.58
Gross margin/sales	.36	.34	.27	.24
GS&A/sales	.21	.22	.19	.14
Profit after	.05	.09	.08	.04
Inventory/sales	.21	.23	.22	.16
Fixed assets/sales	.48	.71	.67	.62
Total assets/sales	.91	1.26	1.33	.78
Capital expenditures/sales	.07	.16	.11	.04
Sales per employee	$91,321	$102,489	$68,522	$76,811
R&D/sales	.06	.09	.03	.04
Advertising/sales	.016	.022	.030	.001
Profit after tax/assets	.062	.061	.045	.050

Note: *Variables are computed as the average for 1977 and 1982 for each firm, and aggregated to create quadrant averages.

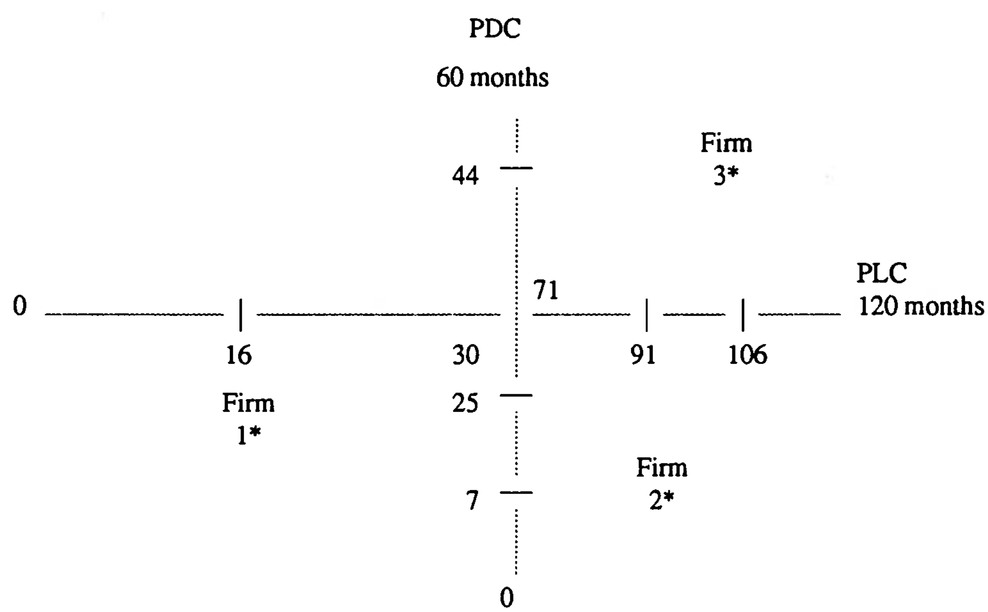
In the tire industry, the three firms participating in this study show dramatically different cycle characteristics. One of the firms exhibits extremely long development and life cycles; a second has much shorter development cycles, but relatively long life cycles; and the third experiences very short development and life cycles.

This pattern also appeared in other industry groups. In the computer industry, with the largest number of firms in this sample, a wide variety of positions are observed. A similar dispersion is evident in other industries. Individual industries may have prevalent cycle characteristics, but firms within any industry may exhibit a wide range of development and life cycle patterns. This dispersion may account for the relatively weak relationships found in examining average cycle characteristics and structure and performance variables by industry, in contrast to those found in examining firm-specific characteristics. That observation begs a larger question: Do predetermined industrial characteristics shape corporate management and organization practices, or can firms select the operating characteristics of their preference without concern for technology conditions?

A more specific research question is: To what extent do industries support a diversity of business and organization formulas? One way of thinking about that issue utilizes the cycles grid in Figure 2.

A position in any of the four quadrants of the grid can be described in generic strategy and organization terms. Any of these positions is theoretically associated with a certain approach to operations, organization, and management relative to competitors in different positions. Each position may also be closely linked to specific subsegments of the industry's technology and customer base. Before developing the hypotheses that follow from this

FIGURE 6.
Cycle Characteristics in the Tire Industry



perspective, it may be useful to examine firms that fall into different quadrants in the computer industry.

Strategy and Organization in the Computer Industry

Three firms can be used to define key generic positions in the computer industry. Hewlett-Packard occupies a position approximating the industry average for development and life cycles. Apple Computer exhibits significantly shorter development and life cycles than the average for the industry. IBM occupies the upper right hand quadrant.

Apple's strategy, organization, and management appear ideally suited for a short-cycle environment. Apple has very low fixed assets; in fact, fixed assets total less than 5 percent of sales. Apple relies heavily on outside suppliers and distributors; it exhibits an extremely low level of vertical integration. As a result, it reports extremely high sales per employee, and asset turnover rates several times higher than industry averages. It also spends well below the industry average on research and development. Apple relies heavily on external sources of technology. In contrast, note the high levels of R&D spending and capital investment by IBM.

Apple has been widely known for its loose management style and anti-structured approach to product development. Managers have been known to award large cash bonuses and other rewards to individual employees, outside of the formal compensation system, for extraordinary performance. It has also experienced a turnover rate within its top management ranks of over 20 percent per year.

IBM, in contrast, operates in a highly vertically integrated manner. It produces most of its components and sub-assemblies in-house, and has relied on internal research to generate new technologies. IBM operates with tight management plans and controls in a highly structured and disciplined organization. Turnover rates among senior management and the company as a whole are very low. The company spends prodigiously on employee training and development. It would be a simple task to distinguish IBM and Apple employees in any industry gathering. Apple's entrepreneurial management culture stands in sharp contrast to the disciplined system at IBM.

These preliminary observations provide two distinct impressions:

- These firms exhibit strikingly different operating and organizational characteristics and
- They are each highly profitable and successful enterprises.

These two firms have adapted to the prevailing conditions in two very distinct segments of the computer industry. Apple's operating and organizational characteristics are finely attuned to the realities of the personal computer industry; IBM has coevolved with the large systems industry. The systems segment requires large-scale development efforts that stretch the limits of science and process technology. Concerns for systems compatibility and security result in extensive planning and coordination requirements. Apple's strategy and organization would be inappropriate in the systems business. IBM was able to participate in the personal computer market only by waiving virtually all of its management structure and practices. The personal computer group was removed from all corporate reviews and controls during the development phase. The PC's microprocessor was sourced from an

TABLE 6
Comparisons of Three Computer Firms
(1978–1987 Averages)

	Key Operating Ratios		
	Apple	*Hewlett-Packard*	*IBM*
Gross margin/sales	.47	.53	.58
GS&A/sales	.33	.38	.36
Profit before tax/sales	.12	.15	.23
Inventory/sales	.16	.16	.12
Fixed assets/sales	.05	.29	.46
Total assets/sales	.56	.85	1.03
Capital spending/sales	.03	.09	.18
Sales/employee	$251,958	$66,047	$100,021
R&D/sales	.06	.10	.06
Profit after tax/assets	.14	.10	.12

external vendor, the operating system came from an independent source, the product was manufactured by a third party, and it was sold though independent dealers; all firsts in modern IBM history. The success of the IBM PC suggests that firms can determine their own destiny. Firms can choose market positions, regardless of technology conditions, as long as they develop the management system most appropriate for that environment. The issue of organizational choice and congruency with technology and market segments appears to be very important in the computer industry.

Hewlett-Packard occupies an interesting position in the computer industry. It is neither a classic short- or long-cycle firm but something in-between. The company's origins are in the instrument industry, and its famed management and organization system, the "HP Way," can be linked to the nature of the instrument industry. HP grew to dominate this industry by introducing waves of product innovations created by individuals or small groups focused on specific applications. The company initiated dozens, even hundreds, of new projects each year, and applied relatively limited controls and reviews to those projects. HP managers enjoyed a high degree of autonomy, and the number of profit centers and general managers proliferated. In contrast to IBM or DEC, Hewlett-Packard exhibits fewer controls, more profit centers, lower emphasis on staff functions, and more individual entrepreneurship. Relative to Apple, however, HP exhibits more structure and systems, more staff, lower management turnover, more emphasis on employee training and development, and higher research, capital intensity, and capital spending levels. The question for Hewlett-Packard might be: will Hewlett-Packard's existing management system be effective in both the personal computer and large systems segments? Does it have the systems, discipline, structure, and culture to compete in the large computer systems market? Can it compete against more agile and flexible firms in short cycle markets? These questions assume a degree of organizational choice, but they also suggest the importance of congruence (Nadler & Tushman 1980). HP's strategy and organization may be appropriate for the instruments industry, but it may not be adequate for managing the large scale, integrated systems development projects vital to success in the mainframe and minicomputer industries. A related issue that arises concerns the degree to which different organizational systems can coexist in the same corporation.

GENERAL PROPOSITIONS

These specific examples help in defining a series of hypotheses regarding the relationship between organization and management patterns and environmental conditions. The baseline hypotheses already proposed include the following suppositions.

Successful firms in short-cycle environments will tend to exhibit:

1. Short-term, variable, equity-oriented compensation based on individual performance;
2. Broader and more ambiguous job descriptions;
3. Less hierarchical organizations;
4. Informal networking;
5. High management turnover.

Successful firms in long cycle environments will tend to exhibit:

1. More internal controls;
2. Extensive accounting and documentation;
3. More formal systems;
4. Narrow, specialized job descriptions;
5. Fixed, long-term compensation.

The computer industry example helps in defining several other hypotheses:

1. Firms whose primary business exhibits long development and life cycles will be ineffective in short-cycle environments, without abandoning existing management systems, structures, and style.

Such firms have developed extensive systems to evaluate and analyze development projects. In many long cycle industries, new projects will be forced to undergo careful, critical screening prior to approval. A survey of firms in this study found that the average pre-approval review process for major projects totalled between twelve and eighteen months. The length of the review process, combined with ongoing review and concurrence activities, greatly extends development time. Such firms will be unable to compete effectively in short cycle industries.

2. Short-cycle firms will require greater leadership qualities in their executives. Long-cycle firms require structured, systematic managers.

The ambiguity and fluidity of job assignments in short cycle firms are not suited to the management systems developed for more stable, continuous environments. Executives in short-cycle firms will need many of the qualities often associated with leaders, as opposed to managers (Zalesnik 1978; Bennis & Nanus 1985). Recruiting profiles will differ greatly for these two types of firms.

3. Short-cycle firms must seek to avoid traditional patterns of organizational evolution.

There is an important distinction to be drawn between start-up firms and short cycle-firms. Start-up firms are often thought of as requiring minimal systems, entrepreneurial management, and organic structures. In fact, start-up firms in long-cycle businesses require formal systems, hierarchical structures, and professional management. Start-ups in the biotechnology or aerospace industry must have these qualities in order to be successful. They need "mature" organizational qualities at an early stage in their development. In contrast, short-cycle firms must retain some of the qualities of embryonic organizations as they mature. Mature short-cycle firms should resemble start-up companies, in terms of organizational qualities. Short cycle firms that evolve and adopt qualities of more mature organizations are unlikely to survive.

The issue facing many firms in short cycle industries is one of organizational evolution. Greiner (1972) proposes that start-up entrepreneurial firms will evolve inevitably toward higher levels of formality in structures, systems, and professional management. The process of organizational evolution may kill the very qualities necessary for the organization's success, however.

The recent record of Mattel Toys Corporation provides an example of this problem. Mattel developed an extensive management infrastructure, a large staff, sophisticated systems, and extensive internal evaluation and analysis procedures. As the organization matured, it became less capable of competing in its short cycle industry. Following poor financial performance in 1986 and 1987, it embarked on a process of eliminating much of the structure, systems, and controls it had taken on over years of organizational evolution. In December 1987, as part of a larger reduction in staff, the Vice President of Strategic Planning at Mattel resigned and stated: "There is no need for a strategic planning function at Mattel." Firms in short-cycle industries must operate, not as start-up companies, but as *start-over* organizations. They must systematize the ability to operate in the fluid, agile, responsive mode so often associated with young organizations.

In the automotive industry, for example, Honda Motors occupies the generic short-cycle position. Honda is able to develop and introduce a new car model in less than three years, compared to an average of four to seven years for other auto makers. Honda's organization and management differs radically from its counterpart companies. It does not have a separate central R&D unit, but incorporates the development function into line management. Its last CEO was appointed at the age of forty-two years, an extremely young age by any standards, typical of the responsibility given to young, innovative managers in the company. The phrase used to describe the development process within Honda translates into English as "noisy." Honda has been the most innovative auto company of the past decade and it has rapidly increased its market share position, so that it is today the top selling foreign car in the United

States. Honda won first, second, and third prize in the 1987 *Motor Trend* Import Car of the Year Awards. Firms may be able to position themselves to achieve such results in other industries if they can develop management and organization models that permit high velocity and short cycles. The extent to which this objective can be achieved in any industry will ultimately be limited by specific technological and market realities. The value of shorter cycles, and the cost and risk of achieving this position, will also vary by industry.

In many industries today, product life cycles are declining. Organizations that have evolved under long cycle conditions may find it difficult to adapt to new realities. Firms organized for shorter cycle conditions may thrive. In other businesses, such as personal computers, growing market emphasis on connectivity, information networks and systems solutions will strengthen the positions of long-cycle firms with the ability to manage complex, coordinated development efforts. In any industry, management practice and organization design must be sensitive to environmental conditions.

SUMMARY

Technology conditions in an industry appear to influence aspects of the industry's structure and performance. Corporate strategy and organization can be influenced and shaped by these environmental conditions. Management practices may differ sharply from industry to industry according to prevailing technology conditions. All aspects of operations, organizations, and management may evolve in predictable ways as a result of sustained technological characteristics in the firm's environment.

At the same time, it is clear that firms in any given industry will adopt strategies that deviate from those prescribed by industry conditions. Regardless of the industry's prevailing technological characteristics, firms opt to operate, organize, and manage according to formulas generically associated with other environments. Competitive interaction and customer preferences, in addition to technological realities, ultimately and dynamically determine industry structure and corporate performance.

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