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By: Caron H. St. John, **Richard W. Pouder**, and Alan R. Cannon

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Environmental Uncertainty and Product–Process Life Cycles: A Multi-level Interpretation of Change Over Time

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ABSTRACT Product-process life cycle models are often used to describe long-term change in organizations. Such models generally assume a deterministic trajectory of long-run industry evolution and production core transformation that lead to standardization over time. Typical interpretations of these models do not explain the short and intermediate term choices and competitive dynamics that lead to the longer-term changes, or explain viable 'off-trajectory' positions and post-stabilization complications that can arise. In this paper, we use multiple theory streams to augment discussions of product-process life cycle models in ways that allow interpretation of the role of uncertainty and management decision-making for the typical trajectory of standardization as well as off-trajectory and post-standardization phases.

INTRODUCTION

Organizations respond to environments in a variety of ways, most of them with implications for the production system. Product lines or services are trimmed or expanded to match new and emerging patterns of demand. Activities are internalized or out-sourced in response to shifts in the magnitude and locus of uncertainty, as observed in the automotive and computer industries in the past, and now in the entertainment and publishing industries. As technological advancements unfold, and product and market characteristics change, processes are refined or automated, or abandoned altogether as observed in the steel and textile industries.

Scholars attempting to describe such change frequently rely on two models derived from Vernon (1966) that represent the changing nature of product and

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process choices over time. The first model, developed by Abernathy (1976) and Abernathy and Utterback (1978), describes the innovation capacity of the production unit as it moves through stages of growth from a small, technology-based enterprise to a large-volume standard product producer. In this model, product innovations dominate the change activities of the young organization and the production core is kept flexible in order to accommodate these innovations. Over time, as the focus on innovations shifts toward processes, the production core becomes increasingly resistant to innovation as incremental process refinements create a more rigid system. Abernathy's work inspired the second model, a product-process matrix developed by Hayes and Wheelwright (1979a, 1979b). Their matrix illustrates the critical linkages between the characteristics of the marketplace and the production core by proposing fits or matches between stages of the product life cycle (introduction, growth, maturity) and process designs (job shop, batch, or line flow).

Both models have been very influential in the development of the operations and operations strategy research literatures. Both models propose a common path for product-process evolution. In general, the models argue, an initial period of market and technological uncertainties encourages frequent product innovations and appropriately alterable manufacturing capabilities but is followed by the emergence of a dominant design. With the dominant design, market and technological uncertainties decline, market demand increases, product characteristics become more homogeneous, and process innovations and refinements create rigid, albeit efficient, production systems capable of low cost manufacture of standard products.

Both models offer an aggregate treatment of the product-process maturation process for a typical competitor under a specific set of assumptions, namely that uncertainty about market size and requirements, resource availability, and product-process technologies will gradually decline over time. In both models, industry evolution results in homogenized customer requirements and a dominant product-process design, both of which work to stabilize the resource base. Both models, in line with their assumptions about industries, generally describe only one possible path for production core transformation over the long run – from flexibility to efficiency, from low-volume customization to high-volume mass production. Figure 1 illustrates the trajectory predicted by product-process life cycle models.

The traditional prescriptions of the life cycle models do not apply to all industries or to all firms, however. In some industries (e.g., applications software, Internet-based retailing, restaurants, printing services), rapid technological change, irreversibly low entry barriers, or low switching costs allow customers to move freely among a constantly changing field of competitors, which sustains high volatility and makes transition to a more certain state virtually impossible. Some firms initiate or find themselves in off-diagonal positions or niches that support

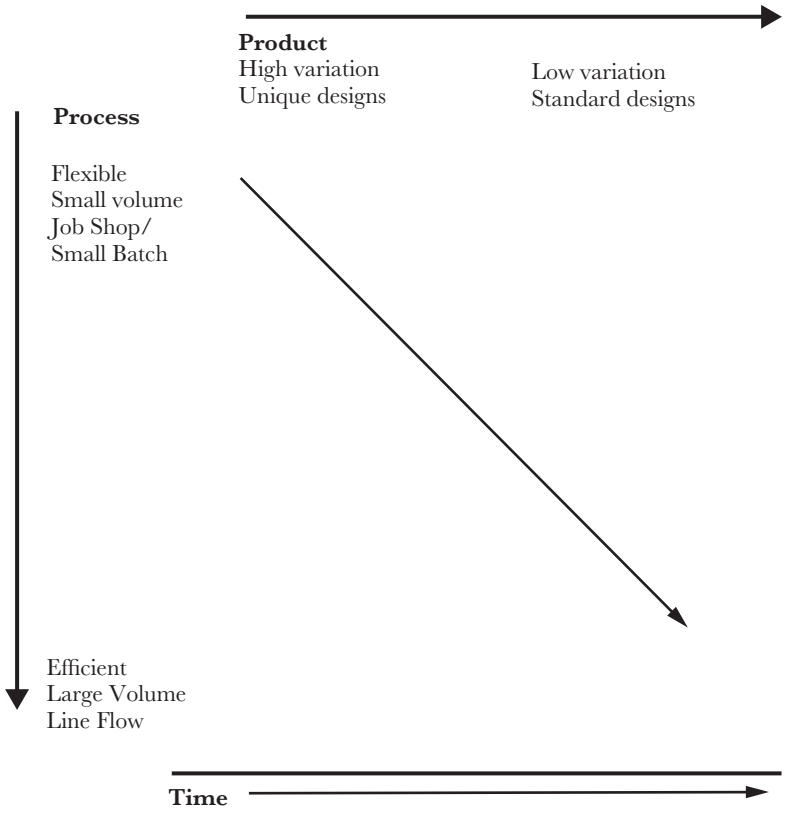

Figure 1. Trajectory assumption underlying Abernathy and Utterback (1978) and Hayes and Wheelwright (1979a, 1979b) models

non-dominant product-process configurations, such as Dell's development of the non-traditional, mass customization mail-order business model. Furthermore, following periods of stability and standardization, industries often undergo a revolutionary environmental transformation (Tushman and Romanelli, 1985) or a competence-destroying innovation (Anderson and Tushman, 1990), renewing the extreme uncertainty of earlier periods and setting in motion processes that lead to new product-process configurations, as in the shift from long-line to wireless communications or the introduction of mini-mill technology to the steel industry. These aborted transitions along the diagonal, viable off-diagonal positions, and post-stabilization transformations are not addressed specifically by the product-process innovation model (Abernathy and Utterback, 1978) or the product-process model (Hayes and Wheelwright, 1979a, 1979b).

We have two main purposes in writing this paper. First, we use multiple theories in an attempt to explain the underlying dynamics of these product-process models. Second, we investigate and offer explanations for situations that defy interpretations within a product/process life cycle framework. Such situations include:

Table I. Change perspectives

Characteristics	*Application*
Life cycle perspective • Unit of analysis is a firm. • Change involves a prefigured sequence of change activities that are regulated by external forces such as institutions or nature (Van de Ven and Poole, 1995). • Change at any one point in time incorporates change(s) from a previous life-cycle stage. • Event progression is always linear, irreversible, and imposed deterministically. • The organization's perception of environmental uncertainty is not as important to the change process as the embedded rules that dictate the sequence.	• Most interpretations of the process innovation model (Abernathy and Utterback, 1978) and product-process model (Hayes and Wheelwright, 1979a, 1979b) are made within a life cycle framework. • The programme sequence consists of: (1) product innovation leading to development of a dominant design that appeals to most users, (2) economies of scale for producers of the dominant design that reduces entry by new innovative competitors, and (3) process innovations that move the production core from job shop-like processes to line flow processes, allowing cost reduction and improvements in efficiencies. • These life cycle interpretations take a long range, largely deterministic view of the production core, with the inevitability of technological innovation and scale effects serving as the embedded rules. Although managers exercise choice in designing products and processes, their decision task is to choose how and when to make appropriate changes that will align the core with environmental realities.
Dialectical perspective • Unit of analysis is two opposing entities. • The dialectical change framework is built on the premise that the entity of interest exists within an environment of conflict (Van de Ven and Poole, 1995). As noted by Zan (1990), a dialectical relationship exists between the firm, its internal systems, and its environment. • The tension between an entity and its source of conflict can produce one of three possible end states: (1) stability, if the balance of power is equal, (2) overthrow, if one entity is more powerful, or (3) synthesis of a new entity if one entity forces the change on another.	• Dialectical conflict can exist between production and the organization, often represented by marketing, and between production and the environment. For example, in many organizations, the marketing group, in the face of demand and competitive uncertainties, attempts to pull production toward broader product lines and differentiated end-items, while managers within production resist movement away from standardization (Shapiro, 1977). Similar dialectical relationships may exist at different points in time with suppliers, labour groups, and R&D. • These dialectical relationships can drive significant change in the production core over time as periodic discontinuities between the environment and the core provoke change responses. The tension and incongruity between a job shop production system in

Table I. *Continued*

Characteristics	*Application*
	an environment of increasing standardization would be an example of the action of the dialectical change model.
Evolutionary perspective • Unit of analysis is the population of like-firms. • The progression of change activities is analogous to the evolution of a biological population involving a cycle of variation, selection, and retention (Van de Ven and Poole, 1995). • Environmental conditions create selection mechanisms that isolate one set of organizations from another, resulting in populations of firms with similar resource profiles and characteristics. • As individual firms then produce innovative changes, they create variations that may or may not be selected positively by the environment (Baum, 1996). • Within this framework, the environment defines a resource path that an organization must follow if it is to be selected for and survive over time (Hannan and Freeman, 1977; Ulrich and Barney, 1984).	• The evolutionary model is used to explain why some organizations survive and others do not. A firm-level variation that is not consistent with the resource path specified by the environment (Ulrich and Barney, 1984) may result in failure. • For example, in some industries, the environment selects those organizations that are vertically integrated, with firms without vertical linkages suffering a competitive disadvantage. • Furthermore, the resource path that the environment selects may change over time, as evidenced by the dominance of vertically integrated, continuous process mills early in the life of steel manufacturing, followed by the dominance of mini-mill technologies in the present day.
Teleological perspective • In the teleological change framework, the entity deliberately takes action to reach an envisioned end state (Van de Ven and Poole, 1995). • Change occurs as a discontinuous sequence of goal setting, implementation and adaptation. • The organization's environment and resources constrain what it is able to accomplish and uncertainties in the environment can cause the entity to alter its change path. • It is through the managerial action of the teleological model that the variations and differences are created among firms, which can then set off a cycle of variation, selection, and retention within the population of competitors as explained by the evolutionary model.	• Within the production core, changes initiated by management in response to threats or opportunities in the environment would be examples of activity of the teleological model. • Examples of changes that can be explained from a teleological perspective include implementation of manufacturing strategic plans, just-in-time programmes, continuous improvement programmes, quality certifications, and investments in automation to improve consistency and lower costs.

(1) industries and firms that are resistant to emergence of a dominant design and transition along the diagonal; (2) the potential for viable 'off-diagonal' or niche positions; and (3) the extension of the models to a post-standardization stage. Throughout this paper, we will draw from Van de Ven and Poole's (1995) extensive review of change models, in which they identified four basic motors of change: life cycle, evolutionary, teleological, and dialectical. Table I provides a definition of each change perspective, with an example of its application to the technical-production core.

As Van de Ven and Poole (1995) suggest, each change perspective offers an explanation for the sequence of events that occurs during a change process. Two of the change perspectives, life cycle and teleological, address change of one entity, such as an organization or a production core. Two change perspectives, evolutionary and dialectical, describe change of two or more entities, such as a population of like-firms or two opposing entities. Furthermore, two of the perspectives – life cycle and evolutionary – describe change processes as largely deterministic, with the external environment driving the need for change and dictating the characteristics of successful firms. The remaining two perspectives – teleological and dialectical – acknowledge the role of managerial choice in change efforts, incorporating more of a postmodern focus on individual organizations and their idiosyncratic events and capabilities as a basis for change and adaptation (Scott, 1998).

Using the change and development perspectives discussed by Van de Ven and Poole (1995), we show the interplay of four change perspectives (teleological, evolutionary, life cycle, and dialectical) during early and late stages, and in the critical transition points initiated by dominant designs and industry transformation. We approach change as a co-evolutionary process, which is, as described by Lewin and Volberda (1999), the 'joint outcome of managerial intentionality, environment, and institutional effects' (p. 526).

The life cycle and evolutionary change perspectives are implicit in most interpretations of the Abernathy and Utterback (1978) and Hayes and Wheelwright (1979a, 1979b) models. By adding dialectical and teleological change perspectives, we can build on the role of the human actors in the system and enrich our understanding of the underlying micro-level dynamics. Whereas the life cycle change perspective may be used to describe the aggregate industry-level movement toward standardization over a long time period observed in many industries, the teleological, evolutionary and dialectical change perspectives allow exploration of the firm-level product-process choices and the competitive dynamics that develop *within a stage* and in the transitions *between stages*.

Following Lambkin and Day (1989), we use product class as the unit of analysis rather than an industry or a specific product group, but we frame our discussion in terms of (1) the decisions made by management within the individual firms in the product class, and (2) the behaviour of the populations of firms within the

same product class. Industries are often comprised of a mix of non-competing products, each product having its own life cycle. Product groups, at the opposite extreme, represent a specific type of product in a given class – for example, PC microprocessors classified into product groups according to processor speed. Because product class reflects both rivalry and new product introductions across all product groups, it provides a more appropriate, aggregate view of the overall life cycle pattern (Lambkin and Day, 1989).

A MULTI-LEVEL MODEL OF PRODUCTION CORE CHANGE OVER TIME

In our model, an overview of which is illustrated in Figure 2, we integrate the four change perspectives at different points in the life of a production core in order to demonstrate not only macro-level interpretations commonly associated with these models, but micro-level decision making as well, consistent with a post-modern interpretation. We will organize our presentation in phases: (1) early phase, (2) later phase, and (3) reorientation, with particular emphasis on the two transition points between phases. Throughout, we will attempt to show how the change perspectives may be used to explain the interplay and accumulation of changes over time, for production cores and populations associated with particular product classes. We will address the production core within a larger organizational and environmental system, introducing the conflicts and tensions of the *dialectical* perspective. In our discussion, managers are goal directed, take action, and make strategy choices, which is consistent with the *teleological* perspective. The innovative strategy choices made by managers create variations among organizations, whereas imitative strategy choices lead to an increasingly homogeneous population. In line with the *evolutionary* perspective, some of the variations are selected by the environment and others are not, which results in some organizational deaths, and a change in the constituents of the population. Some decisions made by managers are not truly free choice, but are instead constrained and prescribed by basic economics or physics/technology (e.g., state of the art of technology, economies of scale, scarcities), or imposed by institutional forces (e.g., regulatory agencies, international governments), which is consistent with the *life cycle* perspective.

Early Phase

In most start-up situations, the environment is characterized by high levels of uncertainty in aggregate levels of demand and in customer expectations regarding product characteristics, quality, price, and delivery. Resource availability and supplier capability are also uncertain, and technology options are unproven. Track records of experience with competitors, which can reveal competitors' capabilities

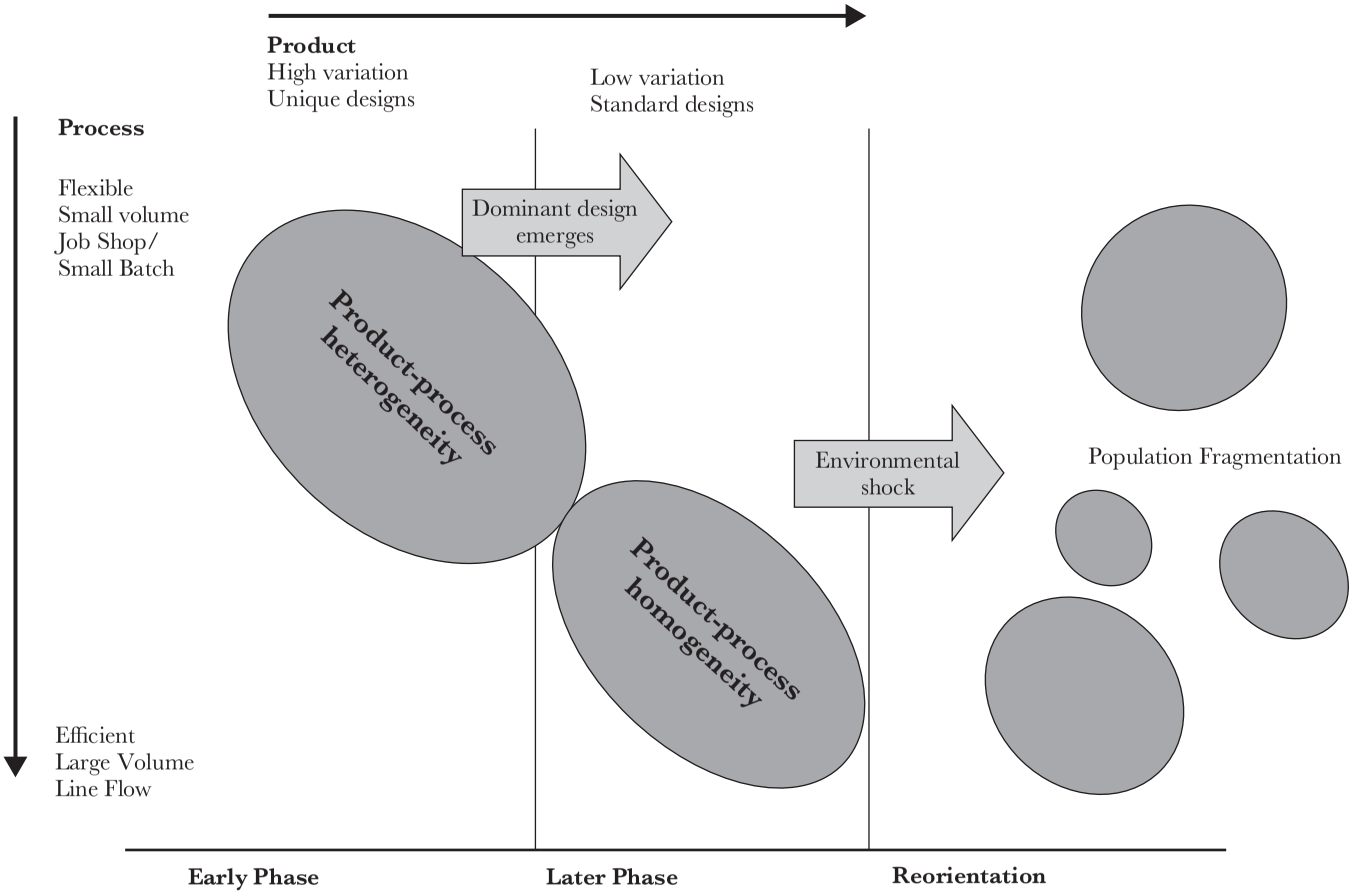

Figure 2. Product-process model: phases and reorientation

and intentions, do not yet exist. During this early phase, customer expectations about product designs are poorly understood. These characteristics of a typical early life of an organization suggest that managers make most decisions under conditions of extreme uncertainty, particularly with regard to market demand. The new firm generally focuses its efforts intensely on product development in order to carve out a position with a small, identifiable group of customers (Abernathy and Utterback, 1978; Hayes and Wheelwright, 1979a, 1979b).

The earliest years of the personal computer industry provide an illustration of the uncertainties and typical firm responses in the early phase. During the late 1970s and early 1980s, many new start-ups formed to serve the emerging market for personal computers. During those years, market and technological uncertainty was very high, and firms responded with a proliferation of products, with some firms targeting serious hobbyists, and others targeting emerging home, business, and game markets. During those years, operating systems, screen appearance, keyboard functionality, and software applications all differed widely, and channels of distribution were under formation. Firms focused their energies on products designed for very specific market niches.

The teleological perspective helps explain the managerial decision-making that accompanies the prescribed life-cycle trajectory in this phase. According to Clark (1985), market and technological uncertainty are preconditions for innovation and change. For innovation and change to occur, managers must face significant ambiguity and numerous choices when designing products as well as uncertainty about which design choices will best satisfy customers (Clark, 1985). This uncertainty triggers a search and learning process that drives innovation and change (Clark, 1985). The search for alternative innovations under conditions of ambiguity involves cyclical processes of adaptive learning and goal formulation (Van de Ven and Polley, 1992), or, expressed in a different way, frequent iterations of product design and test (Brown and Eisenhardt, 1995).

There is an element of randomness to the innovative and adaptive efforts, however, because when technological and market uncertainty are very high, managers cannot forecast accurately which adaptations and innovations will succeed in the marketplace (Baum, 1996), consistent with the evolutionary change perspective. Those firms that are particularly adept at improvization and experience are more likely to be more successful in their product development efforts (Moorman and Miner, 1998).

During this early phase, the dialectical perspective is useful in interpreting decisions about the design of the production core. The market uncertainty of the early phase, coupled with the firm's iterative design and test posture, create tension within the production core. Any efforts to increase scale economies, improve efficiencies, or standardize inputs are generally stopped in the face of high uncertainty about product designs and market requirements. The production core closely resembles the 'Marshallian Market Word' of production described by Salais

and Storper (1992) with the quest for new markets and new product configurations coupled internally with a search for production flexibility and a focus on economies of scope. Production managers are encouraged to adopt job shop and small batch production configurations (Woodward, 1958), flexible general-purpose equipment, with decoupled production stages that allow buffering of each process stage from uncertainty (Aldrich, 1979).

At the level of the product class, the appearance is of firms producing a wide range of product variants using a similarly wide range of administrative and production structures (Utterback and Abernathy, 1975; Utterback and Suarez, 1993). During the early phase, new firms and established firms enter the market in small numbers and make small overall contributions to technological progress and growth in productivity (Klein, 1977). Anderson and Tushman (1990) characterize this phase as an era of ferment in which firms compete with innovative product designs, thus creating tremendous variation among the firms in the product class.

In summary, the many extant product-process variations typical of the early phase of the product-process life cycle are the by-product of goal-directed managerial choice in a highly uncertain environment, indicating that much of the variation observed in the population has its roots in the teleological and dialectical perspectives. Firms that are able to modify their administrative and production structures in response to market and technological change (i.e., those that are 'generalists' best suited to volatile environments) will be most likely to survive (Utterback and Suarez, 1993, p. 5). To the degree that a firm initiates an innovation that is selected positively by investors and customers but is difficult for competitors to imitate, the firm begins to lay the foundation for a competitive advantage (Barney, 1991). Table II provides a summary of the characteristics of the early phase and linkages to the change drivers.

Table II. Early phase and alternative change perspectives

Environment	*High levels of market and technological uncertainty*
Teleological perspective	In the face of high uncertainty, managers initiate iterative design and test as a foundation for adaptive learning and goal formulation.
Evolutionary perspective	Because of high uncertainty, there is randomness to design efforts. The process of variation, selection, and retention will result in some failures and some successes.
Dialectical perspective	There is tension between production's desire for efficiencies and scale and firm's need for flexibility.
Production core implications	The production core exhibits characteristics of the Marshallian Market World of Production (Salais and Storper, 1992): small batch, flexible production, decoupled production stages, outsourcing of some production stages.

Transition Period: Dominant Design

The AU and HW models are both firmly rooted in the concept of a dominant design. The emergence of dominant designs has been observed in a broad range of industries (see Tushman and Murmann, 1998, for a listing). According to the original work of Abernathy (1976) and Abernathy and Utterback (1978), a dominant design emerges deterministically as the best compromise among competing designs, in line with life cycle assumptions about a prescribed sequence of activities, and serves the needs of a large segment of the market. A dominant design represents a specific path along an industry's design trajectory that becomes dominant over other competing design paths (Utterback and Suarez, 1993). The traditional life cycle interpretation of the HW and AU models is that successful firms will align with the dominant design, and transition to what Salais and Storper (1992) describe as the Industrial World of production, or mass production characterized by irreversible investments in economies of scale and process improvements. These life cycle interpretations hold true in many instances. In the early years of the contact lens industry, for example, many firms employed job-shop-like production technologies. When the marketplace signalled disposable soft lenses as the dominant design, firms were required to make substantial investments in mass production in order to survive (Schifrin and Rich, 1984).

Rather than a purely deterministic process, Anderson and Tushman (1990) suggest the emergence of a dominant design is an evolutionary process with dialectical undercurrents. In their view, dominant designs 'are not driven by technical or economic superiority, but by sociopolitical/institutional processes of compromise and accommodation between communities of interest moderated by economic and technical constraints' (Tushman and Murmann, 1998, p. 244). Anderson and Tushman (1990) have described the emergence of a dominant design as a key transition point between an era of ferment and an era of incremental change. Throughout these various discussions of the mechanisms for forming a dominant design, researchers agree that substantial *variation* in product designs and an *accumulation* of those designs set the stage for the emergence of a dominant design. A dominant design is, by definition, a population-level or product class phenomenon since it represents a design that becomes dominant through its adoption by multiple product class competitors within the population to serve a large portion of the total market.

Many researchers have acknowledged that emergence of a dominant design is not an absolute certainty (Tushman and Murmann, 1998; Utterback and Suarez, 1993). Tushman and Murmann (1998) note that dominant designs are unlikely to form when market volumes are small, customer preferences change frequently (as in fashion-oriented industries) and when government regulations constrain variation. A broader interpretation of those conditions would suggest that dominant designs are unlikely to occur when patents, government regulations, or other entry

barriers prevent the *initiation of variations* within the population, or at the other extreme, when competitive behaviour, customer preferences, or geography create a series of small, fragmented, or unstable markets, thus preventing the *accumulation of variations*. Furthermore, in some situations, the dominant design emerges as the only viable alternative for survival (e.g., disk drives), whereas in other situations the dominant design serves a large segment of the market, but viable niches exist for non-dominant designs (e.g., office suite software).

Genetically modified plants provide an interesting example of the emergence of a dominant design. Over the past 20 years, virtually all US seed companies have employed a soil bacterium to insert genes into the DNA of various crops to provide herbicide tolerance and pest resistance. As a result, these plants have moved from the university and corporate laboratories to agricultural fields, and are planted on millions of hectares. Recently, the US Patent Office issued a broad patent to Washington University covering the soil bacterium insertion process, 17 years after the original version was filed. The technology is licensed exclusively to Syngenta and is, as noted by one of the inventors, '. . . the basis for practically all plant genetic engineering these days' (Stikeman, 2001, p. 31). If a broad patent had been issued 15 years ago, with an exclusive license to one key competitor, it is likely the activities of other researchers would have been blocked – resulting in a new direction for their development efforts, and a failure to accumulate such strong momentum in support of this technology. While strong patent and intellectual property protection are often cited as promoting innovation, in rapidly changing industries such as biotechnology such policies may actually stifle the free flow of innovative ideas (Shulman, 1995) and prevent or delay the accumulation of variations that result in the emergence of a dominant design.

Teleological and dialectical perspectives. The life cycle and population interpretations discussed above do not convey the extraordinary uncertainty that managers face in their decision making during this time period. As noted, extreme uncertainty about customer requirements and market potential are the precondition for the search process (Clark, 1985) and the creation of product variations (Tushman and Murmann, 1998) that lead to the emergence of the dominant design. Except in those cases where government regulations create a clearly defined standard, the emergence of the dominant design will likely occur unpredictably. For product class incumbents, the uncertainty of the early phase makes it difficult to discern the emergence of a dominant design – to recognize that one combination of design attributes is beginning to develop broad-based market appeal. Even when an incumbent recognizes the emergence of an apparent dominant design, management must make decisions whether to align with the dominant design, as well as the timing of the alignment. All of these decisions are characterized by uncertainty and conflicting expectations imposed by customers, marketing, operations, and technology management. As exemplified by Sony's failure to recognize VHS

as the dominant design in video formats, even sophisticated, well-established firms have difficulty recognizing an emerging dominant design that works against the established beliefs of management.

A firm may lead or follow the emergence of the dominant design, reject the dominant design altogether, or miss out by trying to align too late with the dominant design. Suarez and Utterback (1995) note that firms may have some leverage in enforcing their product as the dominant design when they possess collateral assets such as market channels, brand image or high switching costs. A firm may also have increased opportunity to have its product serve as the dominant design when it is able to manoeuvre into a position that generates large volumes (Suarez and Utterback, 1995), as in the case of government contracts or extensive network relationships that lead to early scale effects. In introducing Windows, Microsoft used its position with DOS as a collateral asset in striking contracts with computer makers to position its new product as the dominant design. Other firms, lacking those resources, are generally followers along the dominant design trajectory and become imitators of the notable successes of the lead firm. They, in essence, begin the transition to price-based, commodity-like competition when they imitate rather than innovate in their pursuit of market share.

Some firms, when faced with evidence of an emerging dominant design, may choose to jump off of the trajectory, either dropping the product altogether or moving to a niche that is not served by the dominant design. In the early 1980s, Intel was producing a dynamic random access memory (DRAM) chip. During those years, Intel observed that the dominant design was allowing entry by new competitors who had little design capability but were highly competent in low-cost production. The price erosion and lack of differentiation that accompanied the emergence of a dominant design caused Intel to deliberately withdraw from that product segment and focus its energies on other product categories where product design capability continued to have value (Burgelman and Grove, 1996). Similarly, in the late 1980s, Apple Computer rejected the dominant DOS/Windows design, adamantly adhering to its proprietary operating system. In order to survive, it identified niche markets and applications (e.g., desktop publishing, architectural design) where its product provided performance far superior to that of the dominant design. Similarly, Geoworks was a successful developer of operating systems software and one of the first developers of a graphical user interface for Intel-based computers. When Microsoft began to dominate the PC market, Geoworks was able to survive by finding viable niches in operating systems designed for hand-held computing devices and other consumer electronics (Savitz, 1996). For firms that elect an off-diagonal niche position, they continue to operate in a Marshallian Market World of Production, characterized by continued high levels of market uncertainty and flexible production systems designed for rapid development of new products and service to niche markets (Salais and Storper, 1992).

Because of environmental uncertainty, indecisiveness, or a lack of resources and capability, firms may move too early or too late to align with the dominant design, poor timing that will likely lead to failure. Ashton-Tate, the maker of the dBase database software that dominated the market in the 1980s, failed to prepare effectively for the emergence of integrated office suites. It lacked the more extensive product development skills needed to compete with suites, and was unsuccessful in developing those capabilities through acquisition. Even though its position with dBase could have provided powerful switching costs and an opportunity to lock-in some parts of the emerging office suite market, it was unable to make the transition to that emerging dominant design.

The range of these decision options and possible outcomes illustrates the interplay between teleological and dialectical perspectives, as choice is influenced by the expectations of different functional groups within the organization and pressures from the external constituents. As noted by Burgelman (1994), changes in strategy are subject to strong inertial forces. Organizational history, emotional attachment, and bounded rationality can distort the decision-making process (Burgelman, 1994), causing the organization to ignore the signals of an imminent dominant design or to make ill-timed and ill-formed strategic choices. The contributions of the evolutionary, teleological and dialectical perspectives to the dominant design phenomenon are summarized in Table III.

Later Phase

With adoption of a dominant design, the population of firms that adopted the design moves from an era of ferment to an era of incremental change (Anderson and Tushman, 1990). For firms that follow the dominant design, the later phase is generally characterized by lower levels of uncertainty in demand, resources, technology and competitor behaviour. The dominant design achieves wide market acceptance (Utterback and Suarez, 1993), which reduces demand or market uncertainty. The standardization that results from acceptance of the dominant design reduces technological and resource uncertainty. Although competitive *intensity* remains high, the uncertainty associated with competitor actions is reduced as competitors move toward the dominant design. The locus of competition shifts toward acquiring scale economies and achieving cost reductions. The scale effects provide an incentive for even new entrants to align with the dominant design (Utterback and Suarez, 1993). In general, organizations following the dominant design have more knowledge about the expectations of customers, the successful practices of key competitors, and the roles of other institutional forces, such as regulatory groups.

During this phase, the life cycle interpretations of the HW and AU models highlight the predictable trajectory toward process standardization. The HW model proposes that firms shift from flexible, small batch processes toward more efficient,

Table III. Dominant design and alternative change perspectives

Evolutionary perspective (three possible outcomes of variation, selection, and retention)	*Teleological and dialectical perspectives*
Insufficient variation or insufficient accumulation of variations = *no dominant design* →	• High market and technological uncertainty • Continued design and test, with search for market niches • Continued focus on production core flexibility (Marshallian Market World of Production (Salais and Storper, 1992))
Sufficient variation and accumulation within dominant segment = *dominant design with some viable off-diagonal market niches* →	• Reduced market and technological uncertainty • Increased internal tension and uncertainty about existence of dominant design, and whether and when to align • Choice to adopt dominant design moves production core along the diagonal toward dedicated inflexible structure focused on economies of scale and efficiencies (Industrial World of Production (Salais and Storper, 1992)) • Choice to reject the dominant design commits production core to continued flexible production within market niche (Marshallian Market World of Production (Salais and Storper, 1992))
Sufficient variation and accumulation applied to total market = *dominant design as only viable evolutionary path* →	• Reduced market and technological uncertainty • Increased internal tension and uncertainty about existence of dominant design, and whether and when to align • Choice to adopt dominant design moves production core along the diagonal toward dedicated inflexible structure focused on economies of scale and efficiencies (Industrial World of Production (Salais and Storper, 1992)) • Choice to reject dominant design and exit the product class

larger volume line-flow processes in order to capitalize on product standardization, in line with Salais and Storper's (1992). Industrial World of production. The AU model notes that the shift toward standardized production techniques is accompanied by an emphasis on process innovations in order to encourage higher levels of efficiency and further cost reductions. Product innovations, which were the hallmark of the early phase, fade in importance as process innovations become essential to further cost reductions and 'optimization' of the production system (Abernathy and Utterback, 1978). One of the key contributions of the AU model is to note that the movement toward standardized, high volume production often

creates a rigid core that is resistant to further product innovations (Abernathy and Utterback, 1978).

The teleological change perspective sheds light on the strategic choices that motivate production core behaviour in the later phase, particularly the transition toward rigidity (Child, 1997). In contrast to the early phase where uncertainty drove the search process that led to product-process variations, in the later phase, the reduced uncertainty and emergence of a dominant design results in more informed strategy choices that are less likely to be life-threatening. Managerial decision-marking in this phase is characterized by a rational search for efficiency in the production of the dominant design, since cost competition will be increasingly important (Utterback and Suarez, 1993). Managers take full advantage of their more certain environment and initiate tighter linkages between production stages, as is typical of automated line flow processes. Once those capital-intensive line processes are in place, organization priorities shift to full utilization in order to achieve efficiencies. Therefore, changes in processes are oriented toward enhancing efficiency. Changes and modifications that interfere with utilization are resisted, because the human actors adhere to the rules embedded in the process technology (Child, 1997). The production core becomes increasingly rigid to innovations of any kind because change threatens the stability. There are many examples of firms and product classes in this situation. Synthetic fibres, including nylon, polyester, and olefins used for various fabric, carpet and industrial applications, are produced in large continuous process plants that are completely ill-equipped to handle product variety or significant product innovations.

Faced with intense competition but armed with more information about the successes and failures of competitors, some firms economize on search costs (Cyert and March, 1963) and imitate the actions of other successful organizations (DiMaggio and Powell, 1983; Haveman, 1993). In addition to similar product designs, firms will imitate process improvements and organizational innovations. Just-in-Time, Total Quality Management, and team-based production structures are examples of process and organizational innovations that have been imitated extensively.

Researchers have observed that organizations tend to move through protracted periods of stability when environmental uncertainty is relatively low (Gersick, 1991; Tushman and Romanelli, 1985). During stable periods, firms often make minor incremental changes but, for the most part, follow a consistent approach (Anderson and Tushman, 1990; Gersick, 1991; Tushman and Romanelli, 1985). Their successes reinforce a particular way of doing business, which lends validity to the existing strategies, systems, and structures, further reinforcing those decisions and behaviours (Gersick, 1991). As long as the environmental premises underlying the stategies, systems, and structure continue to hold, there is no incentive for the firm to make a significant change in its way of doing business. The firm continues to make minor refinements that draw it into closer alignment with

key customers and suppliers, and that imitate and preempt the routine moves of competitors. These minor adaptations create a deep structure (Gersick, 1991) that becomes resistant to change. Furthermore, during this period of stability, managers further reinforce their mental models about how the industry operates and how the organization should work (Walsh, 1995).

In this later phase, the improvization and flexibility typical in the early-phase product-process actions (Moorman and Miner, 1998) are suppressed by the increasingly embedded practices and routines of the production core (Dougherty and Heller, 1994). As represented by Child (1997), the strategic choices are more likely to make use of predetermined mental models. Organizations use established search routines to garner information (Lant and Mezias, 1992), therefore strategic issue diagnosis is less reflective and more automatic (Dutton, 1993), further perpetuating a sameness to decision making over time. As fewer changes are introduced by the human actors, the production core becomes more of an objective structural component of the organization (Orlikowski, 1992). Put into an institutional perspective, the current product/process configuration takes on a 'taken-for granted' status (Meyer and Rowan, 1977).

In some cases, the market demands new products and innovations that are refused by the large volume, standard product producers. By ignoring these requests, the product class incumbents open the door for new entrants. For example, Fiber Innovation Technologies (FIT) is a small synthetic fibre producer that exists on the fringes of the commodity fibre industry. FIT uses batch processes and flexible equipment to make small lots of specialty shaped fibres for high-end applications. Volumes are too small and production technology too uncoupled and inefficient to attract the interests of the commodity synthetic fibre producers.

This phase is not without the tensions and conflicts illuminated by the dialectical perspective. Many of the internal constituents that had advocated the product innovations and flexibility of the early phase, such as the marketers and product designers, are likely to continue to initiate innovative changes. As Shapiro (1977) has noted, there is a predictable set of conflict areas that exist between marketing and production as marketing seeks product variety and custom solutions while production seeks standardization and large volumes. As noted by Dougherty (1992, p. 179), 'Departments are like different "thought worlds", each focusing on different aspects of technology-market knowledge, and making different sense of the total. Organization routines separate rather than coordinate the thought worlds.' Because significant product changes are costly and they threaten existing processes, systems, and powerful managers, they are likely to be resisted (Miller, 1993). Management innovations, which have difficult-to-measure benefits, are likely to be resisted as well (Kimberly, 1981). Whereas in the early phase the dialectical tensions precipitated changes, in the later phase, the dialectical tensions exist but are unlikely to bring about significant disruption to the stability of the core.

Relationships with external constituents would likely show a reduction in dialectical tensions from the early phase. Institutional theory stresses that organizations must conform with the norms of their environments if they are to receive support and resources (Meyer and Rowan, 1977). In the first early phase, conformity to the expectations of constituent groups is difficult, because uncertainty is so high that organizations do not have a target for imitative and alignment efforts. In the later phase, the norms established by customers, suppliers, regulatory bodies, and financial institutions would be more apparent and easily adopted. As Meyer and Rowan (1977) have noted, 'independent of their productive efficiencies, organizations which exist in institutional environments and succeed in becoming isomorphic with the environment gain legitimacy and resources needed to survive' (p. 352).

The interplay between the teleological and evolutionary perspectives is illustrated in the population dynamics of this phase. From the point of view of the evolutionary change perspective, as competitors facing reduced uncertainty elect to make the transition to mass production, and as that successful variation is then retained, the surviving organizations will begin to take on a certain similarity in strategy and resource profile (Baum, 1996). The tendency toward imitative strategic choices and alignment with industry norms would encourage homogeneity rather than variation, manifesting itself as mimetic isomorphism at the population level (DiMaggio and Powell, 1983). The trend toward increasing similarity among firms is supported by institutional theory. Consequently, the evolutionary cycle of variation, selection, and retention will play very little role during a protracted period of industry predictability or convergence (Gersick, 1991).

These periods of population-wide inertia may be observed in several industries. In the US automobile industry in the 1970s, all three of the big US auto-makers had formed very similar fixed assumptions about what customers wanted, made tremendous investments in similar rigid production cores, and formed tight links to suppliers (including vertical integration) and the dealer network. Rather than initiating significant innovations of any kind, which, in their eyes, would have been risky and unnecessary, they made minor incremental changes that resulted in a high level of similarity among firms and, in a relatively certain environment, ensured survival. Table IV summarizes the evolutionary, teleological, and dialectical change perspectives for the later stage, as well as the production core implications.

Transition Period: Shock and Reorientation

Significant environmental shifts are often referred to as environmental jolts or Schumpeterian shocks (Barney, 1991; Schumpeter, 1934). Examples of shocks include the emergence of new competitor groups, shifts in technology, and substantial changes in market demand – all examples of a return to extreme levels of uncertainty. According to Tushman and Anderson (1986), a competence-

Table IV. Later phase and alternative change perspectives

Environment	*Reduced market and technological uncertainty*
Teleological perspective	With reduced uncertainty, decisions and strategies first become more informed, then more reflexive. Reduced need to scan environment leads to entrenched mental models and deep structure. Failure to recognize impending shocks.
Evolutionary perspective	Imitation among competitors and tacit agreement to participate in marginal change activities leads to homogeneity. Few variations initiated.
Dialectical perspective	Departments become more decoupled and autonomous, resisting changes initiated by the other. Reduced dialectical conflict as firm reaches harmony with its external constituents. Failure to bring controversial information into the debate.
Production core implications	Continuous refinement of coupled processes, leading to efficiency and rigidity. Objective is to reduce costs and develop closer alignments with customers and suppliers. Focus on process improvements, with resistance toward product changes.

destroying or competence-enhancing discontinuity – a form of shock – creates technological uncertainty and obsolescence of extant product and process skills in firms, often resulting in new dominant designs (Tushman and Anderson, 1986). Research by Christensen and Rosenbloom (1995) shows that incumbent firms are often the initiators of new competence-destroying innovations, when those innovations address the needs of existing customers. These innovations often generate a new dominant design, which can fundamentally disrupt existing production cores. On the other hand, Christensen and Rosenbloom (1995) found that a radical technological substitute that displaces existing competitors, rendering product, processes, and technological capabilities obsolete, is more likely to come from a new entrant. Some shocks, such as those created by disruptive substitute technologies, are of such magnitude that they jeopardize the existence of organizations and entire populations (Christensen and Rosenbloom, 1995). Several industries are susceptible to these kinds of shocks now. In telecommunications, for example, new optical fibres are being developed from high performance plastics with the potential to displace glass. Similarly, there are new emerging technologies for optical switches used in broadband communications, with some companies making commitments to micro-mirrors and others developing polymers with optical selectivity. These new technological innovations have the potential to displace existing technologies as well as the companies who make them.

Whether the shock is endogenous or exogenous in origin is an important distinction because of the implications for uncertainty and management decision-making. Using the framework developed by Milliken (1987), uncertainty may be conceptualized as state uncertainty, effect uncertainty, and response uncertainty.

In the event of an endogenous shock – e.g., a competence-destroying innovation that originates within the product class – firms are likely to be aware of the existence of the pending disruption, but may be uncertain as to the effect it will have on their organizations or the response they should take. In the event of an exogenous shock, firms are often completely unaware of the impending threat and fail to recognize the evidence that would have provided the clues. In that case, state uncertainty is high and, consequently, effect and response uncertainty are similarly extremely high.

Teleological and dialectical perspectives on shock. According to Meyer (1982), an organization's ability to *anticipate* a shock is determined by the aggressiveness of the organization's environmental scanning activity. Furthermore, the organization's ability to *respond* to a shock is influenced by the interdependencies that are institutionalized through its structure and process (Meyer, 1982). During the maturity stage, organizations will have become accustomed to lower levels of uncertainty, which reduces their interest and involvement in aggressive environmental scanning and their ability to accurately anticipate a shock (Meyer, 1982). Organizations with adaptive search routines are better equipped to respond to significant environmental change (Lant and Mezias, 1992).

In the period leading up to a shock, the deep structure and the entrenched mental models can prevent managers from recognizing impending environmental uncertainties. Even when new uncertainties are recognized, managers are often reluctant or unable to initiate changes because of the dominance of the deep structure. The longer the period of stability and inertia, the more rigid the organization is to change and the more susceptible it becomes to a significant shock (Barron et al., 1994; Ingram, 1993). For example, the demand and technology shift toward a networked-PC configuration provided a significant shock to minicomputer makers. Similarly, the move toward warehouse-style superstore retailing caught department store retailers off guard. In both cases, the industries had undergone a relatively long period of stability, which had reinforced existing models of customer and competitive behaviour. As noted by Christensen (1997), managers often choose inappropriately in the context of a disruptive innovation by ignoring or resisting its adoption. For several years, Kodak resisted the transition from photochemical film and camera technology toward digital technology, which caused a late shift to that new paradigm.

In addition to mental models and organizational deep structure, institutional forces work against recognition of new environmental uncertainties. Firms develop networks of interdependencies with competitors, suppliers, and associations, which enhance legitimacy in the initial stages but become sources of inertia and inflexibility (Abrahamson and Fombrun, 1994) when the environment once again begins to exhibit uncertainty. The institutional processes that helped ensure legitimacy and access to resources in the early phase may cause firms to fail to exercise full

strategic choice (Oliver, 1991) and to be constrained in their ability to change (DiMaggio and Powell, 1983; Powell, 1991).

The steel industry may be used to illustrate this phenomenon. The continuous process steel mills, most of which are large scale and vertically integrated, made those strategy and structure choices in the face of relatively low uncertainty with respect to demand, technology, and competition during the 1940s, 50s, and 60s. As technology, competitive, and demand uncertainties increased in the 1980s (foreign steel imports, emergence of mini-mill technologies, and slowing demand), the continuous mills were too entrenched with their investments and networks of relationships to make changes in a timely fashion. Table V provides an overview of the teleological perspectives on the shock process.

Teleological and dialectical perspectives on reorientation. Following an endogenous or exogenous shock, firms generally undergo a period of upheaval and a return to an 'era of ferment' (Anderson and Tushman, 1990). The unexpected emergence of a substitute good from another industry, for example, could increase demand uncertainty to levels reminiscent of the early phase. Alternatively, the arrival of a competence-destroying innovation could initiate a return to the technological uncertainty absent since the emergence of a dominant design.

It is tempting to treat production core change during revolutionary environmental periods as merely a special case of the early phase. During the early phase, an organization's production core reflects the uncertainties its managers have about their environment and their firm's place in it. As a reorientation period is by definition one in which environmental (market, technology, competitive) uncertainties are extreme, an obvious implication is that managers may attempt to return to a flexible product-process configuration more compatible with that uncertainty, in essence returning to the Marshallian World of Production (Salais and Storper, 1992). Our synthesis leads us to argue, however, that this conclusion is overly simplistic.

The principal difference between managing during the early phase and managing in a reorientation phase is that during the early phase managers are fundamentally unconstrained by factors either internal or external to the organization. At the firm's outset, as described earlier, managers pursue innovative strategy choices as they try to find and occupy a niche within the environment. Only when this niche is occupied do other goals, such as satisfying the needs of a broader base of organizational constituents, become urgent (Wiersema and Bantel, 1992). Thus, organizational inertia is virtually non-existent during a start-up phase, and managers are free to configure the production core as required by the circumstance.

During a reorientation phase, however, managers *are* constrained. They are limited by inertia (Dimaggio and Powell, 1983) and by the relationships the organization has developed over its life. The production core has become rigid to

Table V. Discontinuities/shock and reorientation

Evolutionary perspective	*Teleological and dialectical perspectives on shock*	*Teleological and dialectical perspectives on post-shock reorientation*
Exogenous shock to product class, e.g., competence-destroying innovation *developed by new entrant or substitute product class* or other external factors provoked by economic, political, or ecological conditions	• Return to extreme market and technological uncertainty (state, effect, and response), but many incumbents do not recognize consequences. • Firms with entrenched mental models fail to scan environment aggressively leading to unrecognized signals, and delays in recognizing shock. • Firms that are positioned in more uncertain niches may be better prepared to recognize a shock.	• Institutional relationships restrict exercise of full strategic choice about how and when to respond. • Entrenched mental models cause managers to fail to recognize uncertainties and to apply old models to inappropriate decision. • Uncertainty creates internal conflict and distrust between groups, which delays decision making. • High levels of organizational inertia. • Firms ultimately face decision of moving quickly to a new dominant design employing very different production core characteristics. • Inability or reluctance to adjust production core to new conditions may result in forced exit or protracted performance problems.
Endogenous shock to product class, e.g., competence-destroying innovation *developed by an incumbent*	• Return to high levels of market and technological uncertainty (effect and response). • Firms generally anticipate the shock even if there is uncertainty about effect and response. • Delays in making important transitions opens up opportunities for new entrants.	• Choices about whether and when to move to new dominant design are constrained by networks of existing institutional relationships. • Reluctant return to iterative search and test mode of earlier developmental period. Increased internal tension and uncertainty about existence of a new dominant design, and whether and when to align. • Choice to adopt the new dominant design moves production core backward along the diagonal toward more flexible structure capable of adapting to uncertainty surrounding new conditions. • Choice to reject the new dominant design forces firm into a niche position that may or may not be viable.

substantive change, for example, since such change disrupts the efficiencies that resulted from a protracted pattern of investment and refinement (Abernathy and Utterback, 1978; Gersick, 1991). As discussed in the later phase, the mature organization has developed and optimized a variety of relationships with external constituents – e.g., suppliers or customers – whose desires and needs may not have changed from the later stage (Utterback and Suarez, 1993). Managing production

core change through a reorientation period, therefore, involves balancing the demands of these constituents – or terminating the organization's relationship with them – with the environmental realities of the new era. Organizations are not free to exercise full strategic choice. Clearly, then, both the teleological and dialectical perspectives may be used to explain production core transformation through a reorientation period.

The transition of Kodak from photochemical to digital imaging technology provides a compelling illustration of the difficulty of reorienting within an existing framework of constituents. One of the key strengths of the Kodak Corporation over the last several decades has been the Kodak brand name, which was represented to the consumer through the extensive network of film developing outlets that employed the Kodak system of film development. In the face of a competence-destroying innovation that undermined its film and conventional camera business, Kodak initially continued to incorporate those retail outlets in its digital strategy. The company envisioned a model in which consumers would take photographs with a digital camera, but have the image perfected and printed through the established retail outlets. Through innovations by other digital imaging companies, such as Sony and Hewlett Packard, customers are increasingly able to use their personal computers and printers to print a hard copy of a photo. Consequently, the role of Kodak's existing retail network is becoming much less important – forcing Kodak to rethink its adaptation to the new world of digital imaging once again. Not only has Kodak been forced to rethink its production core and traditional organizational competencies, it must rethink everything about its branding and distribution to customers and possibly sever some important relationships of the past. Industry boundaries have been redefined to include other consumer electronic and printer companies who do not have a long tradition and large resource investment in photochemical photography, as well as many new markets opportunities that extend beyond traditional photography.

As illustrated by Kodak, the production core that emerges post shock is a reflection both of the characteristics of the new environment (Tushman and Romanelli, 1985) and the balance struck between new and/or altered organization-constituent relationships and those relationships that remain unchanged from the maturity period (Cyert and March, 1963). Early in their reorientation responses, organizations are subject to the liability of newness inasmuch as reconfigured production cores will not have been validated by institutional entities (Aldrich and Fiol, 1994). As illustrated by Kodak, although at least some expertise that was valuable in the old environment is still valuable in the new, managers are forced to scan unfamiliar sectors, learn new techniques and develop new relationships after revolutionary environmental change (Tushman and Romanelli, 1985) and to return to the iterative design and test modality of the early phase.

During the pre-shock, later phase, which was characterized by convergence and stability, organizations tend to hire and promote individuals who are compatible

with that environment. They institute formal communication and planning processes, which tend to isolate departments from each other and to force linear, sequential handling of information and decision-making. As a consequence, organization culture and structure is mismatched with the new post-shock environmental realities. After a shock, firms are forced to recreate flexible intra-organizational linkages, such as informal, adaptive communications between marketing and production, and to place individuals who cope well with uncertainty in key management positions. The speed and completeness of these cultural and structural changes influence the success of reorientation. In some cases, the transition may not be possible within the existing organization structure and culture – and a new business unit may be created to address the new realities. Christensen (1997) recommends that the new digital photography opportunities before Kodak be developed in a completely different organizational unit – not in the mainstream business. If developed in the mainstream business, he argues, the company is likely to use digital photography to strengthen the current business model and possibly jeopardize the new market applications.

Firms that survive a shock are likely to be closer aligned with their environment (Meyer, 1982) and thus better prepared to reorient. The firms that are most likely to be aware of the impending shock are those that have avoided protracted convergence, complacency, and inertia. Ironically, those firms could be poor performers who are forced to aggressively scan the environment to ensure survival, recent entrants who have yet to adapt fully to industry norms, or firms involved in aggressive strategic behaviour (niche participants) at the industry boundaries. When the automotive industry suffered a series of life-threatening shocks in the 1970s, analysts believed Ford, a marginal performer even before the shock, would not survive into the 1980s. General Motors, on the other hand, was in a strong position. Instead, Ford, with little to lose, was able to reorient itself more aggressively and more successfully than General Motors, which was the quintessential example of an inertial firm in the throes of convergence.

The characteristics of the production core following the shock depend on the type of shock experienced. As described, some discontinuities create a disturbance that is, for the most part, localized at the level of the production core, as is often the case with an endogenous shock. New dominant designs require new process technologies and possibly new supplier relationships, but the existing base of customers, most other external constituents, and the core technological capabilities remain intact. When the effects of the shock can be contained to the production core, many organizations can successfully transform themselves in line with the new market and technological demands, as some continuous process mills were able to do with mini-mill technology in the steel industry. Even so, some will resist the reorientation and fail. Consequently, following even a production-core localized shock, the number and characteristics of the organizations in the population will change.

When the shock is more profound, as with most exogenous shocks, threatening to destroy the link between the firm and its customer and technological base, survival is less likely. Following a shock of this magnitude, most incumbent firms will fail to make a successful reorientation. The population will no longer exist as the accumulation of a pattern of selected variations. Those firms that survive will do so by identifying viable niches elsewhere, resulting in a virtual dissipation of the former population. As noted by Utterback (1996) and by Christensen (1997), following the introduction of a substitute, or disruptive, technology, rarely do incumbent firms make a successful transition to the new paradigm. The teleological and dialectical perspectives on reorientation following a shock are shown in Table V.

CONCLUSIONS

Encouraged by the extensive use by and importance of product-process models to academics and managers, we attempted to provide a richer interpretation of product-process models and to offer explanations aimed at extending conceptual and empirical research. For our organizing framework, we used Van de Ven and Poole's (1995) perspectives on organizational change and development. Combining these perspectives offered distinct advantages in examining the multi-level nature of process-product models and allowed us to reconcile disparate interpretations across streams of research. In addition, integrating perspectives of change and organization helped to explain multi-level organizational outcomes that are not currently discussed in the literature on product-process models, including viable off-diagonal positions, product classes that fail to evolve through the various phases, and post-standardization effects.

We began this paper by discussing how product-process models interpret the evolution of products and processes as a deterministic trajectory, shaped in large measure by environmental uncertainties, which is most consistent with a life cycle perspective of organizational change and development. Focusing on the production cores within a given product class as our principal unit of analysis, we discussed the interplay of micro- and macro-level processes that occur over time. As products and processes pass through the phases of a life cycle trajectory, organizational populations cycle through periods of variation, selection and retention consistent with the evolutionary perspective. By emphasizing that the production core is a social system, created by human actors and modified and/or maintained by their actions, we then showed how micro-level processes involving managerial choice (teleological perspective) and conflict (dialectical perspective) act to better explain the dynamics that occur within and between phases of product-process models. By explaining the managerial and institutional roles and effects at each of the stages of the product-process life cycles, we were able to explain and interpret the two pivotal transition points in the life of any product class: emergence of a

dominant design, and the reorientation that accompanies an endogenous or exogenous shock to the product class.

Our work suggests research opportunities to examine the many links between levels, and within or across phases, during product-process evolution. For example, studies examining the roles of human actors in new product and process development could be extended in future research to incorporate their effect on how organizations decide whether and when to follow the dominant design, and how well an organization or production core sustains or fails to sustain a shock. Similarly, research attention should be focused on those organizations occupying position that defy the predictions of product-process evolution models and their attendant dialectical and teleological processes. Although beyond the scope of this study, it is important that related research examine the importance of industry differences in explaining product-process evolution. For example, Eisenhardt et al. (1977) describe the importance of maintaining dialectical processes in strategic choices in a high velocity industry. Another related opportunity is to study the organizational effects of shock when a single product and product core are affected. Do firms with diverse product offerings fare better than those that offer very similar products? As we suggested, are marginal or niche players that were unable or unwilling to adopt the dominant in the earlier period more likely to survive a shock? Given the current trend toward consolidation and return to core lines of business, this is an enticing research question.

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