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TECHNOLOGY STRATEGY AND ORGANIZATIONAL LEARNING: APPLYING POPULATION ECOLOGY TO UNDERSTANDING THE INFLUENCE ON FIRM SURVIVAL

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ABSTRACT

A comprehensive technology strategy is recognized as an important tool for managing a competitive organization. In today's fast evolving, and often volatile, business environments learning organizations must develop strategies to effectively manage their technology resources through a continual evaluation of their processes. Drawing from the technology strategy, organizational learning, and population ecology theory, this paper synthesizes the micro and macro dimensions and proposes that implementation of a multidimentional technology strategy has a direct impact on firm survival. Implications as it relates to for future longitudinal research and management practices are also explored.

INTRODUCTION

Developing management strategies in response to environmental fluctuations has traditionally been a theory proposed by leading thinkers in the field (Andrews, 1987; Ansoff, 1986). However, most today would agree that static, reactionary strategy formulation is nearly impossible to maintain in an increasingly volatile business environment. Technology has created a knowledge-based society where organizations have become very effective at learning how to alter their strategic approach continuously to maintain their competitiveness. The notion of organizational learning is not a new concept, and businesses must learn to apply it to not only strategy implementation, but also to management of its technological resources. Firms that successfully and aggressively convert their knowledge into tangible performance parameters increase the likely of sustaining a long term competitive advantage.

To consider an evolutionary perspective of organizational development, academicians must take a longer time horizon to study the effectiveness of strategy formulation on firm performance. Ultimately, understanding firm survival rates provides an insightful view of whether or not certain strategic models work as expected. One of the concepts that originated the longitudinal perspective, in particular studying organizational survival, is population ecology theory (Hannan and Freeman, 1977). Using the biological concept of natural selection, the theory considers firms as a collection and suggests that they increase their changes of survival through strengthening their internal organizational structure. The increased survival rate is attributed to an inertia that provides a stability which allows a firm to withstand tumultuous environmental changes (Aldrich and Marsden, 1988; Hannan and Carroll, 1992).

This paper argues that establishing core technology resources is a primary contributor to creating a structural foundation for many organizations in today's business. This assertion

becomes significantly accurate when firms are facing environmental turbulence that threatens to disrupt normal operations. Technology management then becomes an exercise in designing strategies that strengthen the organization's technological core, rather than one that is reactive to development life cycles or environmental crisis as contingency theory suggested (Freeman and Hannan, 1989). Subsequently, firms must implement comprehensive strategies to effectively manage its technology competencies and to enhance its long term performance, and consequently, its survival rate. Through a synthesis of the literature on technology strategy, organizational learning and population ecology more perspective is provided into the appropriate level of research to understand the interconnection between the concepts.

THE TECHNOLOGY STRATEGY CONSTRUCT

Harrison and Samson (2003) posit that proper management of a company's technology directly impacts effectiveness and competitive status. This notion has been proposed by theorists in the field of strategic management who have long maintained a link between management of technology resources and creating sustainable competitive advantage (Ansoff and Stewart, 1967; Prahalad and Hamel, 1990; Rumelt, 1974; Teece, 1986). Thus, the strategic focus on development, acquisition, and management of technology has become the critical determination of competitive status, regardless of industry.

While early on researchers considered the fields of technology management and strategic management as separate areas of study that has changes over the years. Itami and Numagami (1992) stated that "Technology is the most fundamental of the core capabilities of a firm" (p.199) and that the interaction between strategy and technology had been treated as too narrowly and static, focusing more on the effect of current technology on firm strategy. At one point, in the technology management literature the primary focus was on R&D management at the firm level and the process of technological innovation at the industry level (e.g., Burgelman and Sayles, Nelson, 1988; Utterback, 1994). Others examined management of technology as a determinant of organizational structure (Eccles, 1981; Teece, 1986; Thompson, 1967).

Today, because of the significant influence that technology has on many business operations, researchers take a broader view and consider technology management as a complex activity that leaders must integrate into the strategic planning process. Itami and Numagami (1992) proposed three perspectives on the dynamic interaction between technology and strategy whereby: 1) strategy capitalized on technology; 2) strategy cultivates technology, and; 3) technology drives cognition of strategy. Traditional strategy research focused on the first perspective, which related to the rational planning model, while focus on the third becomes more process and organization-oriented. Considering that technology in some ways pervades most decisions made by organizations, researchers today, as well as practitioners, accepted that technology is a significant contributor to strategy cognition.

The integration of these two concepts, strategic management and technology management, has led to more literature on the combined construct of technology strategy. It often takes a multidimensional view and focuses on issues like the level of a firm's research and development investment, competitive positioning, technology networking, intellectual property protection, and leveraging of innovation as the primary competitive advantage (Kurokawa, Peic and Fujisue, 2005; Lin, Chen, and Wu, 2006; Meyer, 2008; Wade, 1995; Wilbon 1999). For example, the research finds that focus on R&D efforts tends to provide

advantages in technology intensive industries, particularly those participating in networks or located in clusters (Barrios, Gorg, and Strobl, 2006; Drejer, 2005; Galbraith, Rodriguez, DeNoble, 2008). Similarly, substantial investment in product development and innovations has been posited as a providing technology leadership or first mover advantages. This relates to Porter's (1985a) differentiation strategy whereby firms strive to create a perception of uniqueness. Eisenhardt and Lyman (1990) studied the speed with which new ventures in the U.S. semiconductor industry ship their first product to market. Although the technology strategy concept was not their principle focus, they did find that in smaller firms, a formal organizational structure resulted in faster speeding products to market. Also, Bandbury and Mitchell (1995) provided evidence that first-to-market enhances market share and reduces failure rates, particularly when there are many followers.

As a result of this transition toward a more holistic view of technology strategy, there have been many attempts at defining it over the years. Generally, Porter (1985b) suggested that a technology strategy must address at least three broad areas: 1) what technologies to develop; 2) whether to seek technology leadership in those technologies; and 3) the role of technology licensing. In its simplest terms, Zahra (1996a) opined that a technology strategy articulates a firm's plans to effectively develop, acquire, and deploy technological resources that contribute to its competitive position and increases performance. Ford (1988) defined it as a formal plan for technology resources that guides long term decisions related to development, acquisition, implementation, and investment. Further, Wheelwright and Clark (1992) suggested that the objective of a technology strategy is to "guide the firm in acquiring, developing, and applying technology for competitive advantage" (p. 36).

As shown, the authors provide varied efforts on some levels, but overall the definition of the concept is somewhat consistent. However, the idea that provides the most comprehensive view adapts Andrews (1987) definition for business strategy, and states that: "technology strategy is a pattern of decisions that sets the technological goals and principal technological means for achieving both those technological and business goals of the organization" (Adler, 1989, p.2).

The literature also includes several conceptual typologies relating technology and strategy that have proven useful. However, many of the typologies have minimal empirical foundation to support the theoretical assumptions. Much of the earlier conceptual literature focused on technology posture or the pioneer-follower posture only, as pointed out earlier. Adler (1989) cautions that these posture oriented approaches focus to heavily on product technology only and the fact that firms apply different postures to different technology activities. Also, the emphasis of most empirical support for these models is on high technology industries. For instance, the classic Ansoff and Stewart (1967) research studied high technology manufacturing businesses and their effects on business strategy and management structure and found that to achieve optimal profitable results firms must formulate a technology strategy based on a systematic analysis of its technological profile.

As a result of the attention received from the technology strategy ideology, Zahra and Covin (1994) concluded that the literature had at least three areas that future research should address. First, more empirical analysis is needed because the bulk of existing literature then, and now, is conceptual (Adler, 1989; Burgelman and Rosenbloom, 1989, Maidique and Patch, 1988; Morone, 1993; Porter, 1985, Teece, 1986). Several studies emerged over the years to validate the many technology strategy concepts and address the empirical deficiency

(Hampson, 1994; McCann, 1991; Zahra and Covin, 1994; Zahra, 1996a, 1996b, Wilbon, 1999; Zahra and Bogner, 2000). Nevertheless, further empirical examination is still needed as the knowledge in the field matures based on the emerging strategies firms created to handle rapid technological evolution. Second, Zahra and Covin (1994) suggested that any conceptual models proposed for analyzing a firm's technology strategy must be multidimensional. Many researchers have clearly begun to address this issue as most current models propose at least four dimensions.

The final research deficiency in technology strategy research, and the one most important to this paper, is that the performance implications of matching technology policy and business strategy are not well documented. Zahra and Covin themselves found that technology policies varied across different business strategies and other empirical investigations addressed this concern by designing studies to understand the relationship among strategic behavior, technology strategy, and firm performance (McCann 1991; Weisenfeld-Schenk, 1994). Overall, further exploration into technology strategy's impact on long term firm performance is very much needed as most of the empirical studies found in the literature are cross sectional.

In addition to the needs identified above, many technology strategy studies analyzed large, well established organizations. Several authors discussed the need for more research on technology strategy in new ventures (Dodgson and Rothwell, 199 1; Zahra, 1996a). The new high technology venture plays a critical role in a technology's life cycle. Typically, small business' primary function is to diffuse new technologies along the life cycle curve determined by the technological paradigm. Sometimes the smaller firms are limited in their ability to contribute to emerging paradigms and are relegated to supportive roles, while other times the small business pioneer and lead the advancement of a technological system. This paper will explore the deficiency in small business strategy analysis in as well.

Technology Strategy and Organizational Learning

As mentioned previously, early research on strategy, including technology strategy, focused on the view posited by contingency theorists (Andrews, 1987; Ansoff, 1980). That is, to enhance performance, firms should formulate strategies that match their business situation and implement changes as dictated by environmental thrusts. On the contrary, other researchers found that organizations learn over time and that the complex, dynamic nature of any organization's environment precluded deliberate control of strategy formulation and implementation and favors an emergent process (Burgelman, 2005; Mintzberg, 1990; Quinn, 1980). Related to this notion, Itami and Numagami (1992) aligns with Mintzberg's (1990) emergent theory of strategy formulation proposing that strategy evolves through the firms' process of commitment to technological development and innovation.

This evolution or organizational learning concept creates a knowledge-based organization where executives must recognize the importance of technology as a major piece of their corporate strategy puzzle. Firms must learn to adapt new methodologies that integrate how they will manage technology resources if they are to increase financial performance. By learning how to convert implied and explicit knowledge into strategic actions the aggressive organization evolves into an entity which successfully enhances its competitive advantage.

Lasker and Norton (1996) used three major principles to define knowledge management, by hypothesizing that it is: 1) the alignment of business strategy, or the

performance that pushes that strategy, to the organization's knowledge-creation process, 2) improving performance through new core competency development, and 3) maximizing intraorganizational communication. Zahra, Sisodia, and Matherne (1999) suggest that the dynamic interplay between a company's technology and strategies emphasizes the importance of organizational learning and exploits the knowledge creation process. In other words, as previously emphasized, the concept of a learning organization implies that strategy formation is an evolving process that depends on effective knowledge. While Burgelman and Rosenbloom (1989) suggested that technology strategy creation was an evolutionary process that emerges based on organizational capabilities and experiences, Metcalfe and Gibbons (1989) put it succinctly by stating that: "The competitive performance of a firm in the short run depends on the position of its technology within the relevant technology distribution. In the long run it depends on the ability of the firm to maintain a momentum of technological improvement within the constraints of a relevant agenda. Thus, we argue, that competitive performance depends not simply on success of a single innovation but rather success at a sequence of innovations and related post innovation improvements "(p. 160).

Therefore, the use of traditional "fit" or "matching" strategy models appeared inappropriate to understand how technology strategy affects long term performance and another theoretical perspective was needed. This brings us to, Hannan and Freeman's (1977) organizational ecology theories that considered the evolutionary aspects of strategic behavior and evaluated them as a population of firms that survive based on natural selection rather than rational planning. This provides the most appropriate level of analysis to study technology strategy's impact on firm performance over the longer term.

POPULATION ECOLOGY AND FIRM SURVIVAL

Much of the historical strategy research focused on adapting the firm's internal structure to the external environment. Adaptation theory proposed that organizations scan the environment for opportunities and threats, formulate strategic responses considering its internal strengths and weaknesses, and adjust the organizational behavior accordingly (Andrews, 1987). Similarly, contingency theory proposed that organizations match their organizational structure to technology-environment pairs (Thompson, 1967). Several researchers agreed with this premise positing that the key predictor of a firm's performance was the fit between its technological sophistication and organizational structure (Perrow, 1970, Thompson, 1967; Woodward, 1965; Zwerman, 1970). Some studies found that the "fit" between technology and organizational structure was a better predictor of performance than either technology or structure alone or together (Alexander and Randolph, 1985; Fry and Slocum, 1984; Schoonhover, 1981). Even for small business, Randolph, Sapienza and Watson (1991) found that the fit between technology and structure was a significant predictor of financial performance.

Overall, the general view was that contingency and/or adaptation theory's suggestion of properly aligning organizational structure with key elements of the environment through altering strategic behavior was necessary for increased performance (Lyles, 1990). However, due to the dynamic environmental changes that today's organization face, it's very impractical to suggest that a firm can maneuver fast enough in response to challenges. These theories failed to take into account the limitations and constraints on organizations' ability to adapt to environmental opportunities and threats quickly enough.

For this very reason, population ecology theory has been critical of contingency and

adaptation theories. The research suggests that interference by management, such as adjusting core activities (Hannan and Freeman, 1984) or changes that require an alteration in organizational design to match environmental fluctuations (Henderson and Clark, 1990) have a negative impact on organizational performance and long term survival. Freeman and Hannan (1989) stated that they "thought it was a mistake to build models of organizational change that rely on anthromorphic images of organizations or on heroic images of managers; [they] attempted to build a perspective that treats organizations as complex systems with strong limitations on flexibility and speed of response" (p. 426). In other words, population ecology proposes that the macro environmental conditions of an industry determine the limitations of the firms operating within it. Firms influence one another and do not operate in isolation, much like biological organism under Darwanian principles of variation, selection, and retention.

As a result, the Hannan and Freeman (1977) focused on the population of firms as the unit of analysis as opposed to individual firms, suggesting that survival resulted more from natural selection (i.e., metaphorically similar to the biological process of national selection) than any effort taken by management to adapt to its external environment. The main premise was that organizational change over time does not reflect variability in individual firms but populations of inert organizations replacing each other in a natural selection process.

In fact, some research has pointed out that management inference in efforts to adapt to environmental conditions can actually lead to bad decision making, particularly when success-based experiences have influence (Denrell, 2003; March et.al., 1991). In other words, at the organizational level, firms that have experienced success in surviving highly competitive environment tend to adopt strategies that make them better fit that environment through learning and selection. Yet, this process of adaptation which allowed firms to survive in its current environment (i.e., development of structural inertia), causes significant disruptions when the organization attempts to move into new environments, which typically causes them to fail in their pursuits. This is referred to by Barnett and Pontikes (2008) as the “Red Queen” evolution (see also Barnett and Hansen, 1996; Barnett and Sorenson, 2002). The authors further argue that because of their success in current environments, this “Red Queen” phenomenon gives organizations a false comfort level that makes them more apt to pursue new directions, often at their peril.

Structural Inertia

It is important at this time to consider one of the primary concepts of population ecology. It is an organizational tendency to maintain structures regardless of other factors or concerns (Hannan and Freeman, 1984). Inertia in organizations is established by internal and external factors that tend to exert forces on firms and limit their ability to maneuver. Examples of internal factors include sunk costs in plant and equipment, personnel, political coalitions, or policies and standards while external factors include legal or regulatory environments, fiscal barriers, market barriers, and pace of technological change. The main premise of Hannan and Freeman's (1977) argument was that individual firms rarely succeeded at making radical changes to their strategy and/or structure in response to environmental fluctuations. Firms with high structural inertia have a very difficult and slow time adapting to environmental changes and, in fact, this inertia may favor their survival chances at times. Again, Barnett and Pontikes’s (2008) through their study of the “Red Queen” effect in the computer systems industry over more than 40 years confirm this notion by finding that inertia often leads to these

firms becoming the dominant players in current environments, but they fail at a higher rate when moving into a different contextual situation.

Historically, there is also anecdotal evidence to support this position. For example, Hannan and Freeman (1984) pointed out that although IBM made strategy and structure adjustments to adapt to the environmental conditions in the emerging personal computer industry in the early 1980s, inertia prohibited drastic and fast changes. This allowed entrepreneurs to develop new firms (e.g., Microsoft) with different strategies to take advantage of opportunities in the operating systems market, for example. Again, being the dominant player in the computer industry at the time, decision makers at IBM had an 'overconfidence bias' (Bazerman and Neale, 1986) which made them believe that they could compete with the smaller competitors in the quickly evolving PC market. However, as a historical note, IBM was never able to position its products to become a significant player in the market and Microsoft's operating systems products became the dominant design. Ironically, Microsoft was faced with the same inertia issues as it became the leader in the operating systems software environment. While their Windows operating systems business currently contributes to more than half of their business, the 2007 introduction of the Vista platform proved very disappointing and costly to its reputation. They continued to lose money pursuing more nimble competitors like Google in web- based applications while their Vista product faced commercial ridicule from their primary nemesis Apple, who was gaining market share. The debacle with Vista led Microsoft to distance itself from the product and create a Windows 7 platform that it hopes will repair its customer relationships. However, time will tell whether the world of flexibility offered by online services impedes Microsoft's efforts to survive as they cling to relatively old views in a changing world. These are just a couple of examples to illustrate that relatively smaller firms like Google and Apple are more flexible at adjusting to newer environments than larger, inert ones like Microsoft.

Small to Medium Sized Enterprises (SMEs) and Inertia

More recently, the Internet has created an environment that has impacted larger firms and created instability in several industries. Chao and Turner (2001) studied electronic commerce in small to medium sized enterprises and presented a four phased approach where companies move from making minor implementations of Internet technologies to utilizing it as a mechanism in its core business strategy. Contrary to larger firms, smaller organizations increase their chance of survival if they embrace environmental impositions (e.g., the Internet) and integrate them into their strategies. SMEs are better able to make these adjustments quickly and thrive due to their ease with adoption of the Internet as a core operational strategy for their business. Larger firms take longer to adopt newer technologies, which may leave them vulnerable to competitive pressures.

For smaller organizations, structural inertia is not as strong a force in adjusting to change. The relationship between firm size and technological change is dynamic and depends on the nature and rate of technological progress. Early in the industry life cycle while a particular technology is in its infancy, large firms are the dominant innovators. However, as technology becomes more advanced and readily available, smaller firms become major contenders in the industry and sometimes contribute to the demise of the early leaders. This is not a universal pattern and may not apply in all industries, but it appears to be a common scenario for most segments of the business population. In technology driven sectors of the economy, entrepreneurs have generally been the force behind inventions that have

revolutionized business practices. High technology entrepreneurs are the initiators and implementers of reform, forcing the jurassic corporations to at least attempt to reorganize and regroup to deal with the swiftness of the small technology-based business. Considering that good technological choices allow new ventures to position themselves in the market place (Shan, 1990; Zahra Covin, 1994) while poor choices can undermine their performance and survival (McCann, 1991), there is a need for more research on technology strategy formulation and implementation for the SME population.

As such, although several studies have investigated the liability of newness hypothesis and consistently support this argument (e.g., Eisenhardt and Lyman, 1990; Freeman, et.al., 1983; Carroll, 1983). Hannan and Freeman (1984) argued that inertia tends to increase with size not age. Consequently, although adaption is easier for SMEs and often result in success, attempts to reorganize in response to environmental conditions is more likely to contribute to the death of smaller firms than larger one because they lack the resources to counter the negative disruptions that tend to occur resulting from structural changes.

As a side note, an interesting paradox emerges from the population ecology theory. On the one hand, failure to adapt to environmental changes ultimately leads to organizational failure, but there are risks to adaption that threaten institutional stability which may also lead to failure. More specifically, for firms in technology-intensive industries adaptation is important to stay abreast of newer, emerging technologies; however, disruptions in organizational structure, routines, and credibility are sure to result in negative outcomes.

To understand this paradox further, Freeman and Hannan (1990) performed an empirical test of their prediction that adaptive changes in core organizational features in response to environmental conditions increased the risk of organizational mortality. The study involved firms in the semiconductor manufacturing industry where, due to the fast pace of technological change, adaptation is an apparent necessity for survival. The authors found support for their argument that the probability of mortality for all organizations in the semiconductor industry rises when new technologies were introduced. However, as the organization accumulates knowledge and experience with the new technology, the probability of mortality decreases over time.

Overall, population ecology theory is useful for analyzing technology strategy because it focuses on several determinants of organizational survival. It is implied that the stronger the structural forces are during the earlier stages of an organization's strategic development, the more likely a firm is to survive through environmental changes. In other words, strong internal structures (e.g., core technology resources) are critical in determining organizational survival because these basic structures are not likely to change drastically over time (Aldrich and Marsden, 1988; Hannan and Carroll, 1992). Also, if stable technological resources increase inertia, then establishment of a comprehensive technology strategy to effectively manage those resources will contribute to better long term performance and survival even after environmental disruptions. However, rather than alter technology systems to match life cycle or business strategy as contingency theory suggested, firms should design technology strategies to strengthen structural inertia early in the development life cycle, thus increasing chances of survival (Freeman and Hannan, 1989).

It is important to note that the concept of inertia does not suggest that organizations do not change for it is well known that in most technology-related industries changes in strategy and direction is often a necessity to remain competitive. It is implied that firms with

higher structural inertia, this case related to core technologies, are more likely to survive necessary transformations. The primary emphasis here is on developing a flexible technology strategy which simultaneously develops core structural competencies in terms of technology-related resources, but can also explore new opportunities with minimal destruction.

EMPIRICAL RESEARCH ON TECHNOLOGY STRATEGY AND FIRM SURVIVAL

Recognizing that technological change is a critical force in competitive intensity and firm failure, it's been noted that developing comprehensive strategies to management dynamic environments is critical to competitiveness and performance. Since the origination of the population ecology concept there have been many studies that considered change and strategies in technology-based industries as the driving factor. Some have also evaluated decision making as it relates to technology resource deployment. However, the number of studies that used a multidimensional construct of technology strategy is limited.

Table 1 summarizes research that focuses on technology strategy dimensions using long term survival as the primary dependent variable. The dimensions listed are consistent with the most common ones used in the technology strategy literature and are captured from several conceptual and empirical studies (e.g., Adler, 1989; Bell and Mcnamara, 1991; Burgelman and Rosenbloom, 1989; Zahra and Bogner, 2000). The typical empirical research on these themes has been mostly cross sectional. The ones shown here use methodologies typical of longitudinal analysis in an effort to evaluate survivability, although most tend to focus on only one or two key technology management constructs.

Table 1
OVERVIEW OF KEY EMPIRICAL RESEARCH ON TECHNOLOGY MANAGEMENT, ORGANIZATIONAL ECOLOGY AND SURVIVAL

Reference	Focus of the Study	Key Findings
Agarwal (1998)	*Dimensions: Product Lifecycle* Compared the post entry performance of technical and non-technical small firm's products over stages of differing technical activity.	Small firms enjoy higher survival rates in stages of high technological activity using the product life-cycle framework.
Barnett (1990)	*Dimensions: Design, market timing* Investigated organizational mortality of the early American telephone industry between 1912 and 1935 in Pennsylvania and Iowa.	Predicted that technological change does not favor advanced organizations when technologies are systematic. Greater the density of companies in an industry resulted in higher mortality rates in the industry.
Barnett & Pontikes (2008)	*Dimensions: Market timing, dominant design* Focused on 'Red Queen' effect on the computer industry from 1951-1994 to study survival.	Surviving in competitive environments leads to inertia which makes them less likely to succeed in new directions, even though managers are more likely to make the effort to move into new markets due to 'Red Queen' effect.
Baum et. al. (1995)	*Dimensions: Dominant design, networking* Investigated dominant design and competition on firm failure in facsimile transmission technology from 1965-1992.	Found dominant design was the primary force shaping populations dynamics in relation to organizational founding and failure.

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Reference	Focus of the Study	Key Findings
Bruno et al. (1992)	*Dimensions: Design, Positioning, Market timing* Studied the success and failure of 250 technology-based companies in Northern California founded in the 1960s through the late 1980s. Focused on three outcomes: failure, merger, or continued operations and identified patterns that may have contributed to the success and failure of these firms.	Factors predicting failure included product/market problems (e.g., product timing difficulties), product design problems, inappropriate distribution channels, financial issues, and management problems.
Christensen et. al. (1998)	*Dimensions: Market timing, Positioning* Investigated the rigid disk drive industry considering the advantages of first to market	The study found that in the rigid disk market, first to market advantage does not lead to increased survival.
Freeman & Hannan (1990)	*Dimensions: Scope of R&D/Innovation* Examined whether attempts at change involving core technologies increases the risk of organizational mortality. Focused on firms in the semiconductor industry. Hypothesized that offering a new product requiring extensive changes in core technology raises risk of failure.	Length of time in the industry has a Strong and significantly negative effect on probability of failure. Business conditions affected the odds of failure. Subsidiaries of larger firms had lower odds of failure than independent firms. Innovation in the industry and adopting a new technical innovation increases the odds of failure. In sum, technical change at the industry level threatened firm mortality and when new products appeared in the industry, firm mortality rate rise.
Steam et al. (1995)	*Dimensions: Location, Strategy scope* Proposed that survival chances of new firms were best understood by examining effects of location, industry and strategy. Studied 1900 new firms.	Found that firm survival chances were not significantly impacted by industrv. However, survival chances were associated with strategy (e.g broadly focused strategies have greater chance of survival than narrow focused) and location (e.g., firms in urban locations have greater chance of survival than rural locations) and the two way interaction of industry and strategy.
Stuart & Podolny (1996)	*Dimensions: Positioning, Networking, Location, Intellectual Property Rights* Analyzed technological niche positions of the 10 largest Japanese semiconductor producers from 1982 to 1992	Developed a methodology for quantifying the evolution of firms' technological positions and found that a firms may occupy a differentiated technological niche resulted from the R&D of its competitors.

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Reference	Focus of the Study	Key Findings
Tushman & Anderson (1986)	*Dimensions: R&D Investment, Innovation* Examined patterns of change and breakthrough in the minicomputer, cement, and airline industries on their origination through 1980.	Found that technology evolved through long periods of incremental change punctuated by rare technological innovations. The effects of technological change and discontinuity resulted in uncertainty that may either enhance or destroy firm competence. Firms may use R&D investments to shape environmental conditions in their favor and grow more rapidly.
Suarez & Utterback (1996)	*Dimensions: Dominant design* Studying six industries, tests relationship between competitive environment of an industry, and the survival of firms as related to the evolution of the technology on which it is based.	The probability of survival will tend to be greater for firms entering an industry before the emergence of a dominant design than for firms entering after it.
Wade (1995)	*Dimensions: Dominant design, networking* Studied producers of microprocessors from 1971 to 1989 to examine effects of technology bandwagoning.	Organizational support from the firm's community increases success of firms in technology industries.
Westhead (1995)	*Dimensions: Management Experience, Networking* Examined performances of difference types of owner-managed high-technology firms to determine which ones were more likely to grow and survive. Studied 166 firms in Great Britain.	Firm founders with management experience prior to start-up were more likely to be associated with a non-surviving business. Founders who gained experience in non-manufacturing industries were more likely to survive. Also, five characteristics were found to be associated with survival: age, employment size, regional development assistance, large-sized
Wilbon (1999a)	*Dimensions: Posture, Intellectual property rights, Sourcing, R&D Scope, R&D Spending, Product Portfolio, Location, Management Experience* Studied 168 firms that committed initial public offerings in 1992 to determine survival rates through 1999.	Showed position relationship between technology portfolio, scope of R&D, technology experienced executives, R&D spending, and geographic focus on survival using event history analysis.
Wilbon (2001)	*Dimensions: Intellectual property rights, Staffing, R&D Spending, Cooperative Strategy, Sourcing, Management Experience* Examined 34 information technology firms that completed IPOs in 1997 to determine which technology strategy factors impacted survival	Number of Intellectual property rights and robust technology related staff positively influence survival.

Wilbon (2002)	*Dimensions: R&D Scope, R&D Spending, Sourcing, Intellectual property rights, Management Experience* Investigated 95 high tech IPOs in 1992 to determine survival though 1999	Using logistic regression, found that more intellectual property rights, greater technology experienced executives, less R&D spending as a proportion of sales predicted survival

For example, several studies found that the single factor of dominant design was instrumental in firm survival in populations of firms in technology related industries (Baum et.al., 1995; Suarez and Utterback 1995; Utterback and Suarez, 1993; Wade, 1995). Others considered more than one dimension such as Wade's (1995) study which not only investigated product design but the strategy of joining technology communities or technology bandwagoning. He found that organizational level support contributes to the market success of a technology or design. This organizational support provides a level of legitimacy for an industry which attracts more customers and increase sales for the collective. The strategic importance of this is that entry barriers are increased for potential competitors. Also, customers of the firms in the network of organizations are less likely to switch to competitors because of sunk costs and learning curve apprehension. Thus, developing a strategy for organizational support of technologies becomes important because the bandwagoning contributes to the success of the population.

Baum, et.al. (1995) also investigated the link between dominant design and competitive processes and its impact on organizational failures in the telecommunications industry. Their focus was on positive network externalities, or whether consumers value technologies because others have adopted it or something similar. Using organizational ecology in facsimile transmission technology, they found its dominant design was the primary environmental shaping forces of founding, failure and industry competition of the population of firms. In other words, evolving population dynamics were directly and indirectly affected by firms linked with the dominant design of facsimile transmission. The strategic implications are that firms that got involved with the technology before it became a dominant design failed are a much lower rate than those that got involved after.

This goes back to earlier discussions on structural inertia. Positions in technological networks build practices and routines and require investments in human and physical capital that prohibit fast organizational change (Stuart and Podolny, 1996; March 1988). To make significant change at the organizational level often requires radical adjustments in the technological network itself. This dependence leads to an inertia that constrains actions by the individual firm and the collective. The forces referred to in this research are those related to the management of core technology resources and capabilities as explicated in a technology strategy.

Even though these studies demonstrate strong relationships between technology management decisions and organizational ecology theory, the literature needs more insight on a broader strategy function. When it comes to technology management the research must make an effort to evaluate long term firm performance using more comprehensive factors for understanding strategic analysis. The limitations in the literature are the few studies that considered multiple dimensions to investigate the overall technology strategy's impact on longer term survival. For instance, Wilbon (1999) used population ecology as his foundation using survival analysis to supports the assertion that the level of a firm's technology portfolio, scope of R&D, technology experienced executives, R&D spending, and geographic focus

influence survival chances. His multidimensional construct of technology strategy studied the survival rate of small technology related firms going through the disruptive process of an initial public offering (Wilbon, 2001, 2002). However, further longitudinal empirical analysis is needed to understand how evolutionary frameworks influence the relationship among multidimensional technology strategy and long term survival in a more comprehensive way.

RESEARCH ISSUES, IMPLICATIONS, AND CONCLUSIONS

The result of this research synthesis indicates that managing an organization using an appropriate technology strategy matters with regards to long term survival. Today, managing firms of all sizes requires balancing the internal and environmental constraints to develop strategies that take advantage of the opportunities available within specific and accelerating time frames. This is particularly true of firms in technology intensive industries where decision making is a rigorous process and is becoming increasingly complex. Considering the many facets of technology strategy explored in this research alone; managers have several alternate scenarios to evaluate in determining which approach best positions them to compete. Applying a blanket technology strategy that utilizes every dimension is not an efficient use of resources, nor is it an effective tactic to achieve competitive advantage. Therefore, as Burgelman and Rosenbloom (1989) have mentioned, executives need to examine the internal and external environment and identify the forces that shape their company's technological choices. Understanding technology strategy's relationship to firm performance may assist with developing better strategies that contribute to increasing the chances of survival for firms, particularly in small to medium sized enterprises.

Future research should follow the course set out by this analysis in several ways. First, much more empirical support for the various conceptual models identifying the relationship between technology management variables and long term performance is needed. The population ecology view that early development of a firm's core technological resources contributes to long term survival needs to be further validated through research. Second, much of the existing technology management research takes a cross sectional view, neglecting the importance of understanding the long term impact of the technology strategy-performance relationship through longitudinal studies. Cross sectional research has been criticized because "Retroactive rationalization and cross-sectional research, similar to that in the strategic planning literature, suggests the superiority of particular strategies. However, such results are not sustainable" (Dutton and Freedman, 1985, p. 42). Another point is based on Metcalfe and Gibbons' (1989) research which examined the conceptual link between technology and long-run industry performance and found that competitive advantage in the long run depends on the ability of the firm to maintain a momentum of technological improvement through developing a sequence of innovations and post-innovation improvements. This suggests that technology strategy should set an agenda that proposes a continuous flow of technical innovation over the long term. Finally, the dearth of literature on new and growing ventures requires more studies to understand the relationship between technology strategy and long term firm value for this population. Since SMEs play a very important role in a technology's diffusion along its life cycle, more research is necessary to understand the dynamics that impact their performance and survival. Overall, as shown in this paper, the general implication for managers is that developing a comprehensive technology strategy significantly contributes to an increase in firm performance and survival, while not doing so ultimately leading to a weaker organization.

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