# Separating Emerging Technology Trends from Fads in the Face of Rapid Change

by

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Abstract

Information technology has become such an integral part of commerce that it is nearly impossible to do business without it. New technologies are constantly emerging with the rate of change rising exponentially over time. Making the wrong technology choice can be at best costly or at worst fatal to a company. However, organizations and their leaders have historically poor records of forecasting technology changes. Even companies disrupted by a competing innovator generally have known about the disruptive technology but not recognized it as a threat. With such high stakes, this paper reviews available literature to examine the increasing rate of change in information technology, planning strategies, and methodologies for technology forecasting, with the objective of discovering a possible framework for indentifying significant emerging technologies more quickly and accurately, to separate technology trends from fads. The vast amount of information needed to correlate new technologies with social and economic factors make this task very difficult. Companies will need to devote resources appropriate to their role as technology producers or consumers to more proactive monitoring of emerging technologies. But with monitoring and applying a combination of tools and suggested methodologies, it is possible for organizations to make more accurate forecasts.

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## Introduction

### *Challenge and Objective*

There have always been disruptive technologies. The musket and cannon eliminated the longbow and catapult. The personal computer and word processing did away with the typewriter. Digital photography has replaced an entire industry of chemical photograph developing. The Internet has changed business radically and forever. Keeping up with technical change alone is not sufficient, as evidenced by the failure of the technically superior Betamax. Choosing the right technology at the right time is critical. There continue to be boom and bust cycles in technical innovation. VHS won over Betamax, only in turn to be made obsolete by the DVD. But why did the LaserDisc never catch on at all? The Internet did not eliminate “bricks and mortar” businesses as predicted, but led to “bricks and clicks” models. The rate of change in information technology continues to accelerate. The survival of a business cannot be left to best guesses on what the next trend will be, or whether that trend will turn out only to be a passing fad. This paper examines these challenges by reviewing the history of information technology innovation, the changing role of information technology in business strategy, and related literature to explore whether a framework can be developed to more successfully identify significant technology trends more quickly, and separate them from the “also rans” and temporary fads.

### *A History of Information Technology Innovation and Rapid Change*

Although the history of information technology could be said to have started when people first picked up stone tools or a burned twig to leave records on stone cliff sides and caves, most regard the beginning of what has become known as the “Information Age” as the 1950’s. By then the efforts of World War II decoders at Bletchley Park and ballisticians at the University of Pennsylvania and Aberdeen Ballistics Research Laboratory (Weik, 1961) had led directly to the development of commercial mainframe computers from such companies as IBM, UNIVAC, Burroughs and others. More telling, in 1957 the number of workers whose jobs were concerned primarily with handling information exceeded industrial workers for the first time (McNurlin, Sprague, & Bui, 2009). The United States had passed from the Industrial Age to the Information Age.

With this new age came an explosion in technical innovation. In 2005, Luis Roberto Vega-González measured information technology (IT) as a change driver, using a calculation based on the number of innovations factored on an impact scale of 1 (low) to 3 (high) over a number of years, for a resulting change measurement expressed as a number representing the change in information technology over time or dIT/dt (Vega-González, 2005). The average of the change he measured from 1900 to 1960 was 69. In the next two decades it rose to an average of 103, and continued to rise exponentially.

Ken Anderson (2008) relates that in the 1970’s companies recognized the need to create Management Information Systems departments to ensure these expensive assets were effective and available. Commercially written applications, including database management systems, both simplified application development and added the complexity of vendor management and interoperability issues to MIS departments. Richard Nolan (2001) in his Stages Theory of Information Technology Management names this time between 1960 and 1980 as the Data Processing (DP) Era. Anderson goes on to mark it as a turning point in information technology as interoperability required standards, and buying software instead of building it required maintenance and support contracts. Establishing this technology management environment enabled the rapid spread of technology until it became pervasive in business. The downside of widespread adoption was as business became dependent on information technology, MIS departments quickly became backlogged, and business units became less tolerant of the inevitable delays.

The mini-computer provided business units with more local control and faster response in the 1970's and early 1980's, but even greater user control exploded on the scene with the introduction of IBM's "personal computer", or "PC", in 1981. It was not the first "personal computer" (Anderson, 2008), but when unlike its monolithic mainframes, IBM decided to publish the architecture of its PC, it not only engendered a raft of competitors, it launched an industry of compatible hardware and software. That together with the cachet of IBM and the revolutionary personal spreadsheet firmly cemented the PC as a legitimate business machine (Spector, 2006). Business users freed from the control of MIS drove up the number of computers in use from fewer than 90,000 in 1967 to over 30 million by 1986, and at the same time the cost of computer memory dropped from $2 million/MB to $144/MB (Fisher, Anthes & Hall, 2006). Nolan marks this as the point of discontinuity between the mainframe DP Era and the Micro Era.

The rate of change continued to accelerate during the 1980's. Vega-González calculates that the change index jumped from 105.84 in the period between 1970 and 1980, to 184.16 in the period between 1980 and 1990 (Vega-González, 2005). Nolan notes that the now "ubiquitous" PC led to changes in organizational structure, breaking down old management hierarchies as workers were not so much replaced by computers as leveraged with them to become more productive, becoming knowledge workers instead of simply automating tasks (Nolan, 2001). More significantly, this period began the transition to a world changing era, the Network Era.

In the 1980's the Defense Department's ARPANET migrated from a government and academic network to first the non-commercial National Science Foundation NSFNet and finally by 1995 to a fully commercialized public world-wide interconnected network, the Internet (Nolan, 2001). The introduction of the World Wide Web, hypertext markup language (HTTP), and web browser software in the early 1990's revolutionized access to information stored on servers around the globe. Alfred Zimmerman as quoted by Nolan described the Internet as growing at 340% annually during that time, with the number of computers connected rising from 80,000 in 1989 to 1.3 million in 1993 to 2.2 million in 1994. Meanwhile, in corporations, the need to share information led to the growth of local area networks first in departmental workgroups and then organization wide through wide area networks. The client/server model began to take hold, with enterprise applications such as ERP that on mainframes had been difficult to integrate with PCs, and network centric applications such as e-mail, calendars, document sharing. A "best of breed", customized and connected environment emerged (Anderson, 2008).

Proprietary, monolithic systems increasingly gave way to "open standards". Corporate networks adopted TCP/IP communication standards and were connected to the Internet, initiating yet another wave of change. At the end of 1995, when the Internet was commercialized, about one-half of the 90,000 sites on the web were commercial. Less than three years later, the number of web sites had exploded to 36.7 million, about one-third of which were commercial (Nolan, 2001). As quoted by Nolan, Ira Magaziner attributed over one-third of the growth in the U. S. economy from 1995 to 1998 to growth in the information technology industry driven by the Internet. Driven by this rising move to an Internet based economy and a convergence of data, voice, graphics and multimedia on Internet the K. G. Coffman and A. M. Odlyzko estimated in 2001 that between the end of 1994 and 1996, Internet backbone traffic grew by approximately 1000%, dropping back to a more modest 100% growth per year after that, a trend which they expect to continue

(Coffman & Odlyzko, 2002). Vega-González's IT innovation index numbers confirm this rapid trend, putting the rate of change between 1990 and 2000 at an astounding 534.53.

The ever increasing rate of innovation and change in information technology shows no sign of slowing. Computerworld observed in 2006 that between 1986 and 2006, the number of computers in use had jumped from 30 million to more than 1 billion, while the cost of memory had dropped from $144/MB to $0.11/MB (Fisher, 2006). At the same time, the demand for wireless/mobile applications and Internet access is setting the stage for the next information technology innovation upsurge. Recently Jupiter Research predicted that mobile Internet service subscribers would rise from 577 million in 2008 to 1.7 billion by 2013, further predicting that number will represent 50% of total Internet usage (Mobile Internet, 2008). Shown in Figure 1, Vega-González's chart of the rate of information technology change from the distance past to 2000 dramatically demonstrates the rapid acceleration. He extrapolates that the index for 2020 will rise to 40,000. If so, he wonders how people and societies will achieve the required learning and management of so much new technology so quickly.

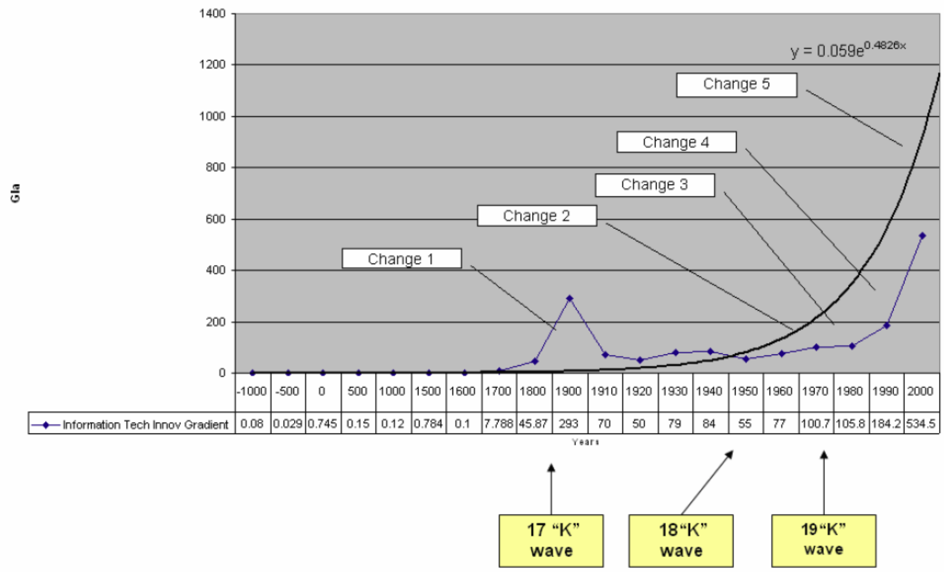


*Figure 1.* Information technology innovation gradient demonstrating rapidly accelerating rate of change (Vega-González, 2005, p.206).

These changes are not just evolutionary, but radical, disruptive technologies, sometimes referred to as “killer applications”, or “killer apps”. Noel Capon and James Hubert characterize killer apps as “not just [changing] a market or industry, rather [changing] the way society itself works and functions. Moveable type was a killer app. The automobile was a killer app…, it changed the way people live, shop, work, and spend leisure time… and it also changed the physical environment in most countries” (as quoted in Morgan, 2003). They compared similar developments occurring every five to ten years during the Industrial Revolution to multiple new innovations appearing now each year. They see this rate increasing exponentially.

## Planning for Rapid Change

### *IT and Business Planning*

The pace of information technology change makes planning both more critical and more difficult. However, pressed by the increasing demands of the moment, corporate IT was slow to catch on to the fundamental transformation that was occurring. Until the 1990’s information technology was still regarded as a means to an end, a supporting resource for greater efficiency in carrying out the business strategy. Quoting Gartner EXP, McNulin et al (2009) describe traditional planning as business executives creating a strategic business plan, then from that Information Systems (IS) executives formulating their strategic plan describing how IT would support the business plan. Finally, an IT implementation plan would be created from the IS plan. The planning process could take over a year and often covered a five year planning cycle. In 1991 Howard Miller commented that most organizations viewed technology as a cost of doing business, focusing on cost reduction. Long lead times led to frustration and a lack of perception of where technology could benefit the organization to evolve with change, to take advantage of opportunities (Miller, 1991).

By 2000 planning literature began to note the rapidly changing environment. John Benamati and Albert Lederer (2000) specifically studied the management challenges associated with rapid change, quoting Manzoni and Angehrn that the world had been changing so rapidly that no steady state could be imagined, especially in information technology. And that Sanders said changes included “drastic, unpredictable shifts”, further noting that the pace of change was accelerating (quoted in Benamati & Lederer, 2000). They concluded that traditional structures could not cope with the demands of this new environment and that new ideas and practices would be required. They attempted to categorize the management challenges to provide a checklist for planning and assessment.

John McCallum postulated in 2001, even after the “dot com bust”, that not only information technology, but the nature of business was changing and enterprises must “adapt or die”. According to McCallum, “The way in which business is done is turning upside down overnight” (p. 72). The climate of change was so pervasive that even the economy came to be called “the New Economy”. McCallum cautioned organizations to make adapting a day to day priority, focus on understanding the business conditions and make the most of opportunity, including restructuring to adapt. Many organizations began to move away from information technology as task automation toward more strategic uses. Nolan (2001) distinguished between Industrial Age companies and Information Age companies by their formal recognition of the importance of information as a resource and its role in adding value to products and services. Nolan used sales per employee (SPE) to measure integration of information technology with business. He reported that as companies moved from DP Era to Micro Era to Network Era practices they increased their SPE at 1.5 times to nearly 29 times the rate of the previous era, with companies putting the most effort into IT enabled features or functions seeming to have higher SPE.

Robert Morgan highlighted the impact of rapid change in 2003, commenting on a chart of management practices from 1922 to 2000, “What is evident . . . is the density of management practices that populate the latter part of this time period. The half-life of management practices since the 1980s appears now to be shorter than ever . . . coming at an exponential rate” (p.38). He warned that Porter’s classic “five forces” framework was an industrial model and that organizations must contend with a new “five forces”, emerging knowledge-era forces that are “more ambiguous, potent, random, and destructive of previously accepted business models” (p.43). To meet these challenges he stresses the alignment of IT and business strategy and goals. Organizations must have a clearer understanding of the life cycle of new technologies, must develop clear plans for targeting, measuring and replacing technologies. However, two years later, in 2005 Colin Thompson observed that in many organizations, information technology was seen as a service provider, instead of participating in the effective business transformation required in the New Economy. His conclusion was supported by a Gartner survey finding that a typical CIO had less influence on strategy than all executives at similar levels, except human resources directors (Thompson, 2005). He reiterates that IT must now be fully and actively integrated into all stages of business planning to meet today's multiple evolving challenges with the agility that is now required.

Clearly, organizations can no longer afford not to include information technology in all strategy and planning, or the luxury of lengthy planning cycles. Organizations must embrace technology and agile response to rapidly changing conditions to stay competitive. However, with a flood of new developments arriving at an ever increasing rate, no organization can devote resources to all the potential innovations. The major question is how to determine which technologies to follow and which can be safely disregarded.

*IT Planning Strategies*

Many different strategies have been proposed and used for information technology planning. Some are more adaptable than others to the rapidly changing environment that has evolved, and all are subject to the differences in organizational culture, structure, industry and competitive environment. One of the earliest and most enduring is the Stages of Growth theory developed in 1974 by Cyrus Gibson and Richard Nolan (Gibson & Nolan, 1974), based on Nolan's observation of s-shaped learning curves of technology adoption and management of computer resources. In this analysis, planning based on four stages: Initiation, the first experimentation with a new technology; Contagion, uncontrolled rapidly spreading adoption with growing interest; Control, management intervention for cost control and standardization; and Integration, maturity and mastery of the technology in the organization (Nolan, 1973). These stages overlap as new technologies are discovered or developed, and the cycle repeats for each.

Nolan used this model to describe the evolution of information technology, with overlapping points of discontinuity between major technology eras. This model is still applicable today, though the curves are closer together than and disruptive technologies can be introduced into the mix at any time.

In 1974 John Rockart developed the Critical Success Factors (CSF) method to assess information needs for executives (McNurlin et al., 2009, p. 147). This method is still widely applied not only in information technology, but other business areas. Although each executive's success factors depend on the unique industry, the organization's position in that industry, economic and market trends, and any current organizational issues, Rockart also found four common factors: service, effective and efficient performance together with the perception of users and management; communication, two-way understanding the environment and needs of key users and their understanding of the information systems environment; human resources, development, management and retention of quality technical personnel; and repositioning the information systems function, from hardware and systems “back office” provider to involvement in all aspects of the business (Rockart, 1982). Rockart was particularly perceptive of the role of information technology in the widespread changes taking place as early as the 1980's. He stressed the need for the integration of information technology in the overall business and particularly strategic business planning. In 1984 he and Adam Crescenzi expanded the CSF concept with the addition of decision scenarios and prototyping (Rockart & Crescenzi, 1984). The combination of these concepts has the potential to allow quick response to changing conditions.

Another advocate of scenario planning, Peter Schwartz, following up on his original 1992 treatise, “The Long View”, described scenario planning as a means of managing the risk of an unknown future that can lead decision makers from the bias of a preferred scenario to consider other options (Schwartz, 2000). More to the point for trend-spotting is that through developing scenarios, Schwartz maintains decision makers can be trained to be more sensitive to new signals of change, with more timely recognition in spite of the flood of information; “What has not been foreseen is unlikely to be seen in time.” (p.2). Scenario planning helps organizations move forward while maintaining links between the organization’s perception and the external environment, allowing them to be more agile and better prepared for either the fad or the trend.

No discussion of strategy would be complete without Michael Porter’s Five Forces. These are forces which, according to Porter, businesses must analyze to understand the industry, the environment and competition: the threat of new entrants, bargaining power of suppliers, bargaining power of customers, threat of substitutes, and rivalry among existing competitors (Porter, 2008). While Porter has used his framework to analyze the Internet (Porter, 2001), believing that despite digitization there is no fundamental change in the rules of competition, this framework provides little guidance in our goal of distinguishing emerging “killer apps” from fleeting fads. As noted by Morgan, many believe that new forces shape the New Economy. Larry Downes and Chunka Mui argued just this point in 1996, calling for a “digital strategy” that specifically accounts for the disruptive force of technology. They advocated continuous experimentation and response over multi-year prediction and planning. They defined the new forces as digitization, globalization, deregulation and “killer apps” (Downes & Mui, 1998). This strategy is in closer alignment with identifying trend-setting emerging technologies. However, Porter’s power of customers force also remains a critical factor.

Similarly, Jeffrey Rayport and John Sviokla warned as early as 1994 that the “information revolution” was transforming the creation and realization of economic value. They focused on the transition from “marketplace” to “marketspace”. The keys to strategy in the new marketspace were to note how competition handles the transition, and to discover and act on new opportunities (Rayport & Sviokla, 1994). Different industries and positions in an industry dictate different strategies such as context-focused or infrastructure based. While not providing guidance on emerging technologies, this framework could help identify possible opportunities and how to incorporate them into the business strategy.

Another strategy mentioned by McNurlin et al (2009) in their case studies is the net-readiness evaluation practiced by Cisco. Developed by Amir Hartman and John Sifonis (2000), directors in Cisco’s Internet business and strategy groups, it is designed to build a strategy for e-commerce using the Internet for competitive advantage. Based on Cisco’s principles of quick and ruthless execution on opportunities, emphasizing metrics, opportunities driven by customer focus, and with a target of producing results within three months, it could be a strategy complimentary to identifying and acting on new trends. Every part of the business must be accountable for thinking in terms of “E-conomy”. Projects are managed in an e-business portfolio matrix. F. Warren McFarlan first introduced managing information systems projects and investments as a portfolio, much like other investments, in 1981. He proposed a similar matrix evaluation of information systems investments (see Figure 2). Cisco has modified this matrix to concentrate on e-business value (see Figure 3).

Low | Strategic importance of HIGH individual applications in the predicted **future** competitive environment | High

| Strategic Importance of individual applications in the **current** competitive environment | | |
|---|---|---|
| High | KEY OPERATIONAL<br>Current IT important but future developments unlikely to improve competitive advantage | STRATEGIC<br>Existing and future IT developments are critical to success |
| Low | SUPPORT<br>IT needed to support the business but of little strategic value | HIGH POTENTIAL<br>Existing IT is unimportant. Future IT developments are critical but value not confirmed |

*Figure 2.* McFarlan's strategic IT investment evaluation grid (adapted from McFarlan, 1981)

Low | Newness of Idea | High

| Criticality to Business | | |
|---|---|---|
| High | Operational excellence | Breakthrough strategy |
| Low | New fundamentals | Rational experimentation |

*Figure 3.* Cisco’s e-business value matrix (adapted from McNurlin et al., 2009, p. 156)

At the same time McCallum was warning organizations to “adapt or die”, Brian Burke of the Meta Group also advised organizations to evaluate technology strategies in the light of the increasing impact of disruptive technologies (Burke, 2001). Noting that only 5% of Global 2000 companies included technology adoption in strategy and planning, he predicted that by 2005, 20% would do not only do so, but establish a technology watch function. The specific strategy depends on the organization's technology adoption profile, e.g., bleeding edge, leading edge, early or late adopters, and their risk profile. However, the crux of the problem remains understanding how a technology will change the market and what impact it will have. Burke suggests assessing risk and reward against the impact of a disruptive technology in selecting an appropriate strategy, as illustrated in Figure 4.

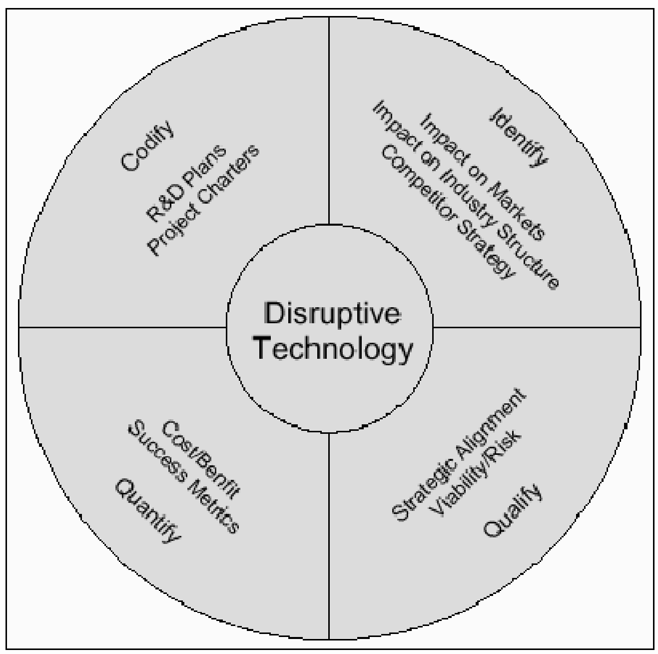


*Figure 4.* Disruptive technology impact assessment; quadrants show areas to assess and evaluate to determine value and risk in developing a strategy to counter or adopt a disruptive technology (Burke, 2001, copyright 2001 META Group)

Up until now, most strategies have stressed agility and adaption to counter or preferably take advantage of rapid or disruptive change. Citing the examples of Google, Facebook and Salesforce.com, most recently John Hagel, John Seely Brown and Lang Davison have argued that adaptation and the “sense and respond” approach that gained popularity in the 1990’s (McNurlin et al., 2009) is no longer sufficient, that it risks missing opportunities. Some companies have become “shapers”, enlisting other participants in a strategy to shape the economic environment into a new market or industry. This strategy is reminiscent of Porter’s value chain strategy (McNurlin et al., 2009, p. 152), but broadened beyond the industrial, product origin of Porter’s model. Salesforce.com used the growing power of customers and digitization to deliver applications as networked based services, and in less than 10 years achieved an $8 billion market capitalization (Hagell III, Brown, & Davison, 2008). Google connects advertisers, content providers and customers with AdSense, providing massive scale to even small websites and advertisers to their mutual benefit (Hagell III et al., 2008). This new view of strategy extends beyond the boundaries of an organization, to form an ecosystem of shapers and participants. Hagel et al outline a process of “FAST thinking”: Focus, Accelerate, Strengthen and Tie it all together (p.87). Through scenario planning, initiatives are selected to enlist participants and move toward a preferred future in an incremental, iterative way, taking short steps to achieve the longer view. The long view is still important, since it disruption is almost constant, without the intervening equilibrium that once allowed first movers to consolidate their advantage. Without that protection, Hagel et al warn that new shaping strategies will be required constantly, since “disequilibrium” is now the rule.

## Forecasting the Unknown

Market forces moving at “Internet speed” have compelled organizations to recognize that any business strategy must be concerned with rapidly changing information technologies; that they must be prepared to respond with agility and speed. No strategy will be 100% successful, but the more accurate the foresight, the better the chances for success. Therefore, the major issue in addressing rapid change and disruptive technologies is accurately forecasting them. But how do you predict the unknown? And how does a market leader possibly challenge its own offerings by exploring disruptive technologies that serve as of yet undefined future customer needs? This is what Clayton Christensen dubbed the “innovator’s dilemma” in 1997 (Christensen, 2006).

Christensen (2006) attributes part of the difficulty in recognizing disruptive trends to organizations and their management having most experience in “sustaining” technology. They work in markets with known customer needs and pursue incremental improvements in products or services: better performance or new features. It can lead to what Jay Paap and Ralph Katz (2004) refer to as the “tyranny of success”, in which market leaders seeking to protect their positions miss the signals of change and instead lose their advantage to a new market entry. First mover advantage evaporates under these circumstances. According to research reported by Paap and Katz, 50% of market pioneers failed and the mean market share of pioneers was only 10%. Their mean period of market leadership was only five years, and they maintained leadership in only 11% of categories over time. That means that these innovators themselves are failing to forecast the significance of change. Traditional forecasting models that may be well suited to predicting demand for current technology are clearly unsuited for identifying new trends, let alone sifting the trends from the fads.

Although it seems that disruptive technologies appear suddenly from nowhere, Christensen (2005) reports that in every case studied, companies displaced by disruptive innovations knew about the new technology, but dismissed its importance. So it would seem predictive information exists, if you knew where to look and how to correlate the data. Just as companies use data mining to uncover patterns in their customers and products, data mining and knowledge management have been suggested to uncover technology trends and identify potentially disruptive technologies. The nature of an emerging technology means that there is little specific history to research. Extrapolation from other data must be used. One method is to search and correlate data from patents and bibliometrics to replace missing historical data, and then combine with expert data, modeling, and scenarios (Daim, Rueda, Martin, & Gerdsri, 2006). Long used to guide research and development (R&D) efforts, the pattern of patent filings can show where investment in development is most active. Because most patents do not result in commercial products, this data is only useful in broad terms. Bibliometrics has been used by researchers to find patterns in academic data, and can similarly be used to uncover patterns of interest in technology or consumer behavior. Daim et al demonstrate possible scenarios for fuel cell adoption using bibliometric investigation to consider economic pressures, developmental stage (lifecycle position), penetration with automobile manufactures, population and vehicle purchase trends, and governmental policies. System dynamics were then used to explore possible models. Other examples were food safety technology and optical disk storage using patent trend analysis. Integrating data mining in this way with other methodologies may improve forecasting, but it is a very complex and arduous process. Recognizing this, these researchers suggest defining different combinations of methodologies for different phases of research, such as data collection, relationship building and diffusion (adoption) study/forecasting. This approach is still theoretical, and its efficacy has yet to be determined. The time to structure and complete this analysis could have serious implications for an organization's ability to identify a trend and respond in a timely fashion.

On the other hand, Marc Henselweski, Stefan Smolnik and Gerold Riempp (2006) report that extensive research has shown that data mining has not benefited forecasting accuracy. They point out that intense competition created by rapid globalization, the increasing rate of innovation leading to short lifecycles, and other new emerging issues puts heavy pressure on the need for better forecasting. Data mining can still be used to help analyze the huge amount of data referenced to define a forecast problem and later monitor results, but other tools are required to manage information in context, which grows in complexity in the forecast process. Topic maps allow the management of large amounts of information, generating new knowledge by also managing its meaning (Garshal, 2002, in (Henselewski, Smolnik, & Riempp, 2006). However, because topic maps require some knowledge of the domain, they suggest information retrieval technology to generate the topic map, which is then used to organize, classify and analyze the information. The topic map can be reused as the technology and its implications are further developed. One challenge to this methodology is the maintenance of the map. New developments must be monitored and added to maintain its relevance. Once established, the profile developed with this method, if properly set up, monitored and maintained, could provide timely knowledge about emerging technology.

Ronald Kostoff, Robert Boylan and Gene Simons (2004) also suggest text mining in conjunction with a roadmap planning strategy. Roadmaps are common in both technology developing and technology consuming organizations to plan longer term technology development or adoption. They reiterate findings that successful companies not only favor low-risk short term gains from sustaining technologies, but that the increasingly common extensive, large committee based technology selection discourages disruptive technology selection and precludes agility. This prejudice must be changed for successful forecasting. One gap in their method is the actual identification of a problem to be solved or opportunity. Once that is identified, text mining is used to define the problem/opportunity and related technologies. Technologies can be further broken down into components which are also researched. Component technologies imply that a shaping strategy or ecosystem approach could be combined with this method. Given the example of traffic gridlock, literature would be mined for all types of traffic, all types of traffic congestion, all types of technology that could be used to move objects or people, and other directly and indirectly related topics revealed by the analysis. The results are filtered by experts and presented as candidates for evaluation by traditional roadmap processes (Kostoff, Boylan, & Simons, 2004). A second possible gap is the selection of the experts and their filtering process, which comprise the actual forecasting basis.

In another approach to the forecasting problem, a process theory based approach is used to relate the complex interaction between components, products, and infrastructure in a "technology ecosystem" (Adomavicius, Bockstedt, Gupta, & Kauffman R, 2008). Similar to the shaping strategy, Adomavicius et al built on research modeling the concept that technologies are comprised of systems or populations whose characteristics change and interact over time, forming complex systems that can be hierarchically organized. Technologies are assigned roles as "components" which are combined into "products" and supported by infrastructure that add value to the products they support. "Paths of influence" are traced between technologies to indicate their influence on each other in the evolution of the ecosystem. Similar to the previous methodologies, literature is scanned for the technologies relating to the target. For example, for digital music, information was gathered on flash storage, LCD screens, MP3 players, digital music services and so on (Adomavicius et al., 2008). Roles were assigned and paths of influence developed. Frequency computations on changes in standard specifications were used in another case as quantitative instead of qualitative information. Patent data could be used as well. As shown in Figure 5, 3x3 matrixes of current roles versus future roles between components, products and infrastructure were converted to state diagrams for pattern analysis. Interpreting the patterns provides possible forecasts for that ecosystem, such as new high density, small form factor storage resulting in the introduction and adoption of digital music services.

| | Component Future State (C*) | Product Future State (P*) | Infrastructure Future State (I*) |
|---|---|---|---|
| Component Present State (C) | Component Evolution. Examples: Moore's law and the continual improvement of microprocessor performance. | Design and Compilation. Examples: Combining of new touch screen components and hand writing recognition software to create tablet PCs. | Standards and Infrastructure Development. Examples: The development of IEEE 802.11 standards for wireless components. |
| Product Present State (P) | Product-Driven Component Development. Examples: New designs for smart phones and PDAs driving development of higher capacity flash-based storage components. | Product Integration and Evolution. Examples: Integration of PDA and mobile phone to create the smart phone for personal computing. | Diffusion and Adoption. Examples: Widespread adoption of personal computers helps drive high-speed internet service development. |
| Infrastructure Present State (I) | Infrastructure-Driven Component Development. Examples: Internet and broadband infrastructure helps drive development of wireless chipsets and multimedia optimized processors. | Infrastructure-Leveraging Product Development. Examples: Internet-optimized PC designs and smart phones designed to utilize the broadband wireless services. | Support Evolution. Examples: Continual improvement of networking infrastructure, such as gigabit Ethernet and fiber optics |

*Figure 5.* Roles and paths of influence in a technology ecosystem (adapted from Adomavicius et al, 2008)

Bruce Vojack and Frank Chambers proposed a similar methodology, termed "SAILS" for "standards, architectures, integration, linkages and substitutions" (Vojak & Chambers, 2004). It similarly looks at interrelated standards, notably changes in standards, different means of serving the same function with different architectures, combinations of subsystems to form new systems or subsystems, linkages as expressed in value chain relationships, and the threat or instantiation of substitutions. It shares the same deficiency as many of the methodologies presented in that it neither identifies methods or tools for uncovering the SAILS information, nor identification of a target technology to which to apply the analysis. It depends on having a candidate target and assumes a separate information research methodology.

Although the "ecosystem" approach looks promising, especially as more analysts and researchers are realizing the impact of ripple effects from one technology change to others, there are three problems evident with this model. First, a target must be assumed. The model does provide a means of detecting changes in ecosystems. The researchers note the need to extend this research with other research to form a more proactive orientation. Secondly, it is technologically deterministic, that is, it postulates the primacy of technological development, that technological development drives social and cultural change, not vice versa. Adomavicius et al recognize the impact of social forces and the argument for social construction of technology (SCOT) theories, but assume these forces are contained in the model by virtue of the mix comprising an ecosystem. Additionally, while they hope to include more of these social drivers in a later, more comprehensive refinement, they have restricted the model to only technical roles and relationships to reduce complexity. That complexity is the third problem with this model. The researchers also assume that this methodology will be used by domain experts to inform others. In interviews conducted across a range of forecasting experts, analysts and senior executives to gauge the potential usefulness of the methodology, most appreciated the clarity of the results, but felt that the methodology would most likely be used by experts presenting analysis to clients, either internally or services such as Gartner or Forrester (Adomavicius et al., 2008).

The drawbacks of the otherwise promising ecosystem model bring up a fundamental issue: is the adoption of technology driven by technical factors or social ones? Christensen and his collaborators hypothesize that predicting change is not about the technology, it is about adoption. Innovation is created when a technology connects with a need, giving the technology value. Technology creates a change in process, materials or functionality. The perceived value of that change Paap and Katz (2004) refer to as “leverage”. Changes with the greatest leverage become drivers in a market. However, over time, improvements in that technology lose value with consumers and reach a “leverage limit” where they are no longer willing to pay for improvements. Without understanding that limit, incumbents listen to customer feedback and innovate in improvements to existing offerings in ways their customers have historically valued, in sustaining technologies. This type of innovation maintains their supremacy in that offering. However, Christensen, Anthony, Paap and Katz point out that disruptive technologies are often not “better” than the technology they replace, they are cheaper, easier to use and “good enough”. They meet needs that customers may not express. In this case, the new entrant dominates. In the digital music example, Adomavicius concludes that MP3 compression enabled software programs to record and store music, which in turn enabled MP3 players, leading to the popularity of digital music. Then, the development of compact hard drives drove the adoption of players such as the iPod, which in turn drove the development of digital music services (Adomavicius et al., 2008). In 2004 Paap and Katz saw the move from CD-ROM to DVD as a result of demand for greater storage for archival storage, not the reverse as Adomavicius argues. The driver, more storage, was the same, the technology changed (Paap & Katz, 2004). Anthony and Christensen saw in 2005 that while companies were producing higher and higher quality compact disks, the technology had overshot “good enough”. MP3 provided lower audio quality, but “good enough,” allowed greater convenience, was reusable and more portable, and disrupted CD players. The demand for customized MP3 selections drove the creation of digital music services that are replacing CD sales. Sony and the Walkman were out, Apple and the iPod were in.

Technology substitution takes place when either the technology or the driver matures, or a new driver arises (Paap & Katz, 2004). In the case of a mature technology, it may have reached not only its leverage limit, but no further significant improvement can be made. The higher risk is a mature driver. It is here that Anthony and Christensen (2005) point out that most incumbents “overshoot” their market. The technology still meets the need; there are still improvements that can be made. The inclination is to try to sell the improvements for the “best”, higher spending customers but little return will be realized from the investment. The new driver is likely to come from either price or convenience, especially from ignored “less desirable” customers for whom the current technology was too expensive or too difficult (Anthony & Christensen, 2005). The replacement driver may not be immediately known until customers with those unmet needs encounter it, setting the stage for disruption. Lastly, the environment may change. It could be regulatory, economic, or another technology. As an example, Whirlpool noticed Burlington Industries’ development of a new wash and wear fabric, developed a washer with a “cool down” cycle tailored for the fabric and surprised competitors.

## Is a Framework for Improved Trend Identification Possible?

Given the accelerating rate of change in information technology and shortening cycles of development and innovation, can emerging technologies be detected and evaluated in time to avoid either investing in the wrong technology or being disrupted by a competitor? The key would appear to be monitoring both the technology and the behavior of consumers. What technologies have “overshot” their market? Are there indications of unmet needs, the “undershot” market that is scooping up innovations searching for a solution? Are there what Anthony and Christensen (2005) call “non-consumers” who can’t afford the technology, need an intermediary to use it, or have limited access? These conditions signal an opening for an emerging technology. The technology landscape must be continually scanned for candidates that could meet these needs. If a candidate does not meet all or most needs for its use, it will not become a trend. Still, making a connection between a technology and a need is not enough. Does the innovator have the resources (economic, process and management) to compete? Is the innovator prepared for competition? Who are the competitors? Which has the better strategy and is better prepared? If these questions can be answered, there is a good chance to identify a potentially successful trend and ignore a fad in the making.

Of the methodologies that have been explored, a combination of tools and techniques are required. None is sufficient on its own. The sheer volume of information, continually growing as change piles upon change makes it virtually impossible to cover every emerging technology. The US Patent and Trademark Office patent grant image database alone is currently over 4.5 terabytes. Correspondence history for patents adds another 33 terabytes (Melvin, 2008). In 2004, storage vendor Infinite Options estimated that US academic research libraries consumed approximately 2 petabytes of storage. The amount of resources an organization can devote to technology monitoring will depend on the organization’s industry, environment, culture and resources. An organization that is primarily a consumer of technology will have very different monitoring requirements than an organization that is technology or research oriented (Nosella, Petroni, & Salandra, 2008). Nosella et al found that, predictably, the more an organization invests in R&D, the likelier it is to engage proactively in systematic and sophisticated technology monitoring.

There are common elements that could characterize a general framework, though. At whatever level an organization chooses to monitor emerging technologies, the volume of information dictates some information retrieval and filtering tool. Patent information, academic research, market information, economic and other contextual factors must be included. This complex and high volume information research suggests some sort of text and data mining tool. Some automation may be possible with query agents or “bots” to trigger notifications if search conditions flag a candidate technology for further inquiry. The resulting information should be subjected to analysis using ecosystem or SAILS type methodology that has been extended to include the social construction drivers, leverage, overshot/undershot/non-consumer, and other social/cultural constructs.

## Conclusion

No organization can expect to be completely successful forecasting the future of information technology. The unknown can only be guessed; until it happens the future is still unknown. The only data available are from the past, which has often led forecasters to dismally inaccurate conclusions. However, the signs are discoverable. It is possible to improve forecasting accuracy, to distinguish a trend from a fad. In every case studied, disruptive technologies were known before displacing an incumbent. An organization can increase the odds of successful prediction by instituting and maintaining systematic technology monitoring on a scale appropriate to its technology role.

However, with globalization and other factors increasing the magnitude and rate of change, the volume and complexity of information that needs to be considered will make it difficult for all but very large organizations that can afford to devote substantial resources to evaluate and respond to emerging technologies in a timely fashion. Further, technology developing organizations must pay close attention to changing market conditions, especially unmet needs and technology changes that can create leverage for new drivers. Both technology developing and consuming organizations must recognize and beware of technology that has exceeded its leverage and is overshooting the market.

An opportunity exists for commercial and academic information providers to create services to track the global environment and technical information using techniques such as data mining marketing databases, demographic data, economic data, social trend data and patent applications. It is the scale of this information retrieval and analysis that is so daunting for average organizations and so challenging to keep current. Sharing the cost of collating and maintaining this information through subscription services could make tracking emerging technologies and the factors influencing their adoption more effective than traditional ad hoc data gathering and lengthy planning cycles. Research firms such as Gartner, Forrester Research, IDC, AMR Research, Aberdeen, Burton Group and others already make a business of information technology prediction. Their analysis and predictions could be greatly improved by objective data retrieval and application of methodologies as suggested by Adomavicius, Paap, Christensen and others noted in this study. Data mining services could also be made available directly to clients. Much of the relevant data already exist in academic libraries which could provide data retrieval and data mining services directly to subscribers and researchers as well.

Regardless of how they obtain the data, organizations need to make greater use of environmental and technological information scanning, closely monitoring the technical and market environment. Ecosystem, SAILS, bibliometric or similar methodologies should be used for trend analysis, with the results providing input to shaping strategies either as a shaper or participant, including roadmaps for technology development and/or adoption. Both technical and business plans must be revisited far more frequently than in the past to avoid surprise and a costly mistake of missing the next trend or backing the next fad instead. It is possible to better identify true trends and separate them from the flash of fads. It will require dedication of resources, but it must become as necessary to businesses as current planning and competitive market analysis activities.

# Appendices

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