JOURNAL OF EMERGING TECHNOLOGIES IN ACCOUNTING American Accounting Association
Vol. 6 DOI: XXXX
2009
pp. 1–XXXX

The Impact of Gartner's Maturity Curve, Adoption Curve, Strategic Technologies on Information Systems Research, with Applications to Artificial Intelligence, ERP, BPM, and RFID

Daniel E. O'Leary
University of Southern California

ABSTRACT: How does technology maturity and adoption affect samples, research issues, and use of methodologies in information systems? What is a source of some research issues in strategic and emerging technologies? This paper addresses these questions and others using some frameworks generated by a well-known corporate research group.

Gartner Group has been an icon to its corporate clients. However, Gartner has received only limited attention by academics. This paper examines three related frameworks used by Gartner for analyzing information systems (IS) and accounting information systems (AIS) research. Although researchers have previously examined the adoption curve, they generally have ignored the impact of the technology maturity curve and the interaction of the two curves. The paper generates a number of findings, including the finding that where a technology is on the maturity curve limits and facilitates the type of research questions that can be addressed regarding that technology. In addition, Gartner's "strategic technologies" can provide a basis for understanding which technologies are likely to be appropriate for analysis by researchers.

Keywords: Gartner; maturity curve; adoption curve; strategic technologies; AIS research; information systems research; artificial intelligence; enterprise resource planning systems; ERP; business process management; BPM; radio frequency identification; RFID.

INTRODUCTION

The Gartner Group provides information about a wide range of technologies, generally to corporate clients, to facilitate the analysis and purchase of technologies. Although Gartner is well-known in practice, there has been limited research in information systems (IS) or accounting information systems (AIS) regarding frameworks used by Gartner for technology

This is an extended version of an earlier paper that was presented at the 2008 American Accounting Association Annual Meeting in Anaheim, CA. The author thanks Paul Steinbart for his comments and suggestions on an earlier version of this paper.

Corresponding author: Daniel E. O'Leary
Email: oleary@usc.edu
Published Online: xx xxxx

maturity or adoption. Further, there has been limited research using Gartner's so-called "strategic technologies." Although O'Leary (2008) initiated an analysis of AIS research from the perspective of Gartner's so-called "hype cycle," this paper analyzes information systems research from the perspective of the maturity and adoption curves, which have found broader-based acceptance.

Purpose of this Paper

Previous AIS researchers (e.g., Murthy and Wiggins 1999) have examined the overall issue of what constitutes research in AIS. Other researchers have suggested the use of particular kinds of research, e.g., case studies (Baker 2002) or design science (e.g., March and Smith 1995), to investigate information systems research issues. However, it is not clear when case studies or other methodologies (e.g., design science) are appropriate, or which technologies likely should be investigated.

In addition, researchers (Sutton 2005) have indicated that AIS is an applied discipline and that AIS research can guide practice. However, there has been limited assessment of the flow of contribution from practice to AIS. By using some of Gartner's models, this paper suggests the notion that practice also influences theory, and that both could gain from taking each other into account.

Rogers (1983) and others have examined the impact of the "adoption curve," e.g., studying characteristics of firms at different stages, such as "innovator firms," for technology diffusion. However, the role of the maturity of technology has not received the same level of attention and has not been juxtaposed to technology adoption.

Accordingly, the specific purpose of this paper is to examine some of the implications of three different theoretical frameworks, used in practice, on research in accounting information systems. In particular, I will examine how the passage of a technology through a life cycle (as captured by Gartner's maturity cycle and the adoption curve) affects the research that is done on or about that technology. In addition, I will examine how using that life cycle can facilitate choice of a methodology and a technology to analyze the effect of the technology. Further, I integrate Rogers' (1983) adoption curve into the analysis in order to drive additional understanding, examining the joint impact of the stage of technology and adoption curve on firms. Finally, I examine the potential use of Gartner's strategic technologies to facilitate the choice of technologies to research.

I find that different research methodologies are appropriate or inappropriate at particular times in the technology life cycle, based on factors that can be identified from the maturity cycle and adoption curves. In addition, I find that empirical research about technologies is vulnerable to sample bias, depending on where technologies are in their life cycle. I also find that the "strategic technologies" concept provides an apparent approach for identifying new technologies research investigations in AIS.

Outline of this Paper

This paper proceeds in the following manner. The first section has provided the motivation and the outline of the paper. The next section briefly reviews Gartner's maturity curve, the adoption curve, and Gartner's notion of strategic technologies. The third section drills down on the maturity curve and its implications for AIS research. The fourth section analyzes in more detail the adoption curve, examining both Gartner's cumulative adoption curve and Rogers' (1983) curve. The fifth section studies the impact of integrating the maturity and adoption curves, and facilitates an understanding that empirical research may be gathering biased samples. The sixth section provides an example to illustrate the discussion, using enterprise resource planning systems. The seventh section examines some extensions to the maturity curve. The eighth section analyzes

Gartner's notions of strategic technologies as a basis of understanding which technologies are likely to have an impact in AIS. The final section briefly summarizes the paper, and discusses the contribution and some extensions.

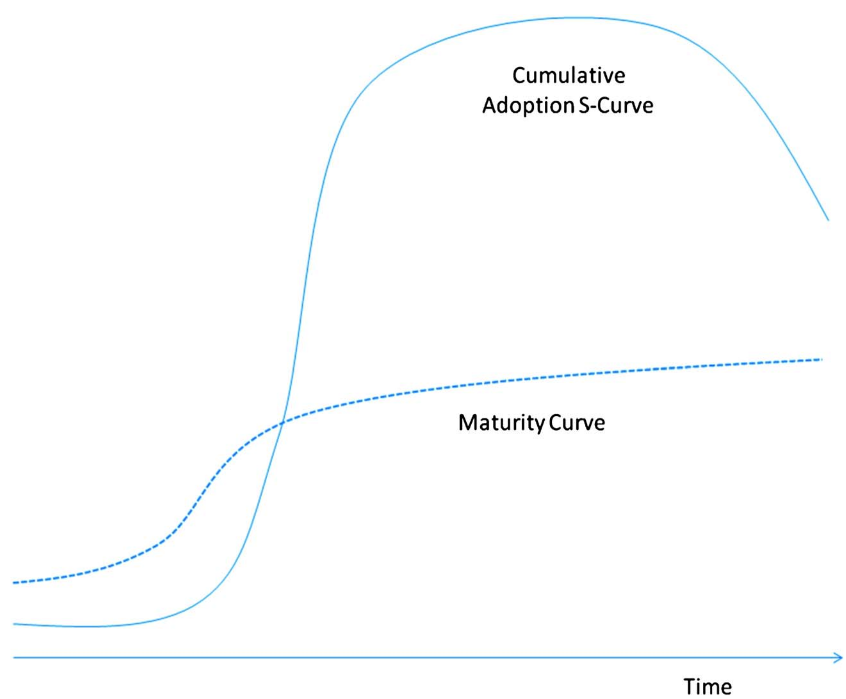
MATURITY CURVE, ADOPTION CURVE, AND "STRATEGIC TECHNOLOGY"

Linden and Fenn (2003, 6; see also Fenn 2007, 7) indicated that "several technology life cycle models attempt to gauge the evolution of a technology. The two most popular are the…[maturity curve], which shows the increase in a technology's performance over time, and the adoption curve, which shows market adoption over time." The maturity curve and cumulative adoption curve are summarized in Figure 1.

Maturity Curve: Technology Change Categories

The maturity curve traces a technology's change over time as it matures to meet user needs, and takes the form of a so-called "S" curve. Effectively, the curve maps the cumulative capability level of a technology. Labels for different stages in the maturity curve have been generated by Gartner and are referred to as the "maturity levels." Fenn (2007) lists key characteristics for the

FIGURE 1
Adoption S Curve and Maturity Curve



Source: Fenn (2007).

seven different levels or stages of the framework (see Table 1): embryonic, emerging, adolescence, early mainstream, mature mainstream, legacy, and obsolescence. The curve can be integrated with the different qualitative levels as seen in Figure 2.

Adoption Curve: Firm Adoption Characteristics

The adoption curve has been presented in two different formats. The cumulative version, used by Gartner, is the adoption curve that traces the cumulative adoption of a technology over time. At the intersection of the maturity and adoption curves, a technology has achieved roughly a 20 percent adoption rate. Further, when cumulative adoption decreases, it indicates that the technology is obsolete and users are shunning it for other technologies.

Rogers (1983) also investigates the adoption curve and includes additional information to the probability density version of the adoption curve (in contrast to the cumulative version), as seen in Figure 3. So-called "ideal" types of firms are generated based on when the technology is adopted: innovators, early adopters, early majority, late majority, and laggards. The characteristics of these levels are summarized in Table 2.

"Strategic Technology"

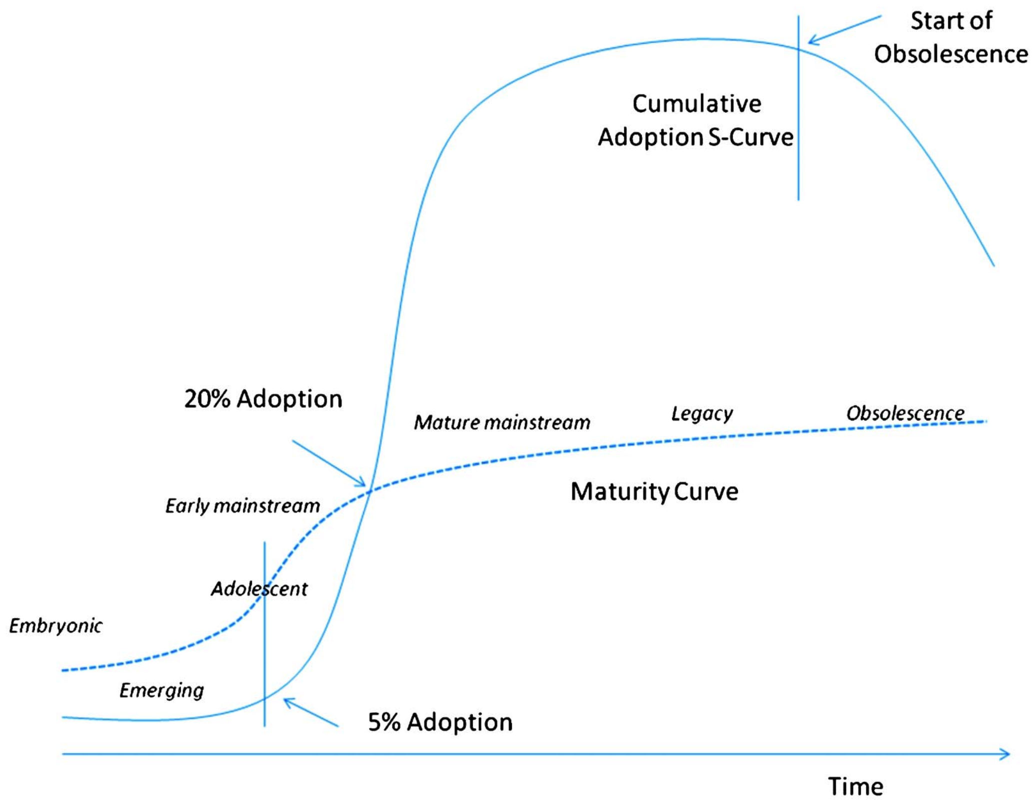
"Strategic technology" is a bit different from the two previous frameworks. The term implies a value to enterprises that is associated with the technology, not just with how mature the technology is or how much adoption the technology is getting. In particular, Gartner (2007) defines a strategic technology as a technology:

TABLE 1
Maturity Levels

Maturity Level	Status	Products/Vendors
Embryonic	In labs	None
Emerging	Commercialization by vendors pilots and deployments by industry leaders	First generation high price much customization
Adolescent	Maturing technology capabilities and process understanding uptake beyond early adopters	Second generation less customization
Early Mainstream	Proven technology vendors, technology and adoption rapidly evolving	Third generation more out of box methodologies
Mature Mainstream	Robust technology not much evolution in vendors or technology	Several dominant vendors
Legacy	Not appropriate for new developments cost of migration constrains replacement	Maintenance revenue focus
Obsolete	Technology is rarely used; new technology has supplanted original technology	Used/resale market only

Source: Fenn (2007), available at: http://www.gartner.com/DisplayDocument?id=509085.

FIGURE 2
Adoption Curve and Maturity Curve with Levels and Adoption Rates



Sources: Linden and Fenn (2003) and Fenn (2007).

with the potential for significant impact on the enterprise in the next three years. Factors that denote significant impact include a high potential for disruption to IT or the business, the need for a major dollar investment, or the risk of being late to adopt.

Unlike the maturity curve or the adoption curve, the notion of strategic technologies is focused virtually entirely on the presentation of ten specific technologies for each year. The strategic technologies for 2004–2008 are summarized in Table 3.

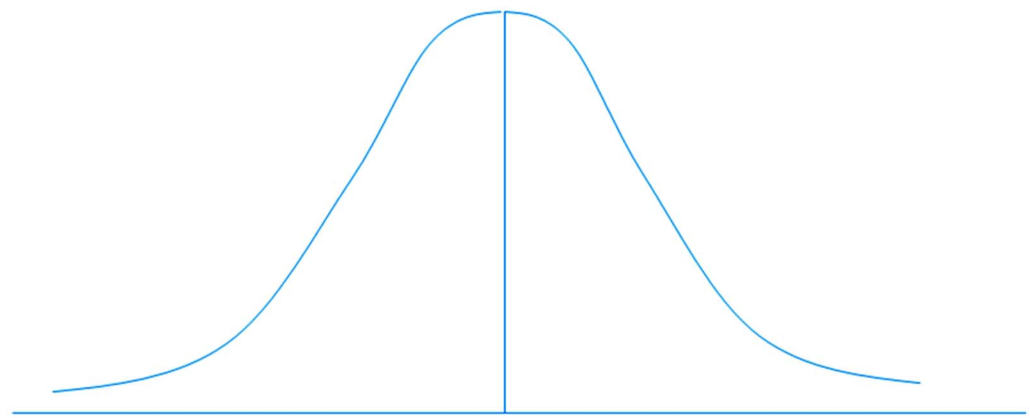
MATURITY CURVE AND INFORMATION SYSTEMS RESEARCH

The maturity level framework provides a view of the use of technology changing over time (Table 1 and Figure 2). We will examine the impact of the technology maturity of a technology on AIS research by examining each of the stages.

Embryonic

The "embryonic" stage is the first stage on the maturity curve. It is at this stage that most hardware and computer science-like research is done and that technology design questions are

FIGURE 3
Adapter Categorization on Basis of Innovativeness



Source: Rogers (1983, 247).

asked. Further, the models that ultimately are embedded in software and applications are initiated at this stage, before commercialization. For example, Hart et al. (1978) developed an expert system in a geology domain that laid out key principles of representing uncertainty in expert systems. This is truly a stage where design science (Hevner et al. 2004) dominates. There is no data for empirical analysis or even case studies of the impact of the technology on organizations, and no actual information about so-called "things gone right" or "things gone wrong" with the technology in organizations, since it has not really been deployed in organizations. However, at this stage, research can begin to anticipate developments and applications by soliciting expert opinion (O'Leary 2002), e.g., in Delphi studies (Baldwin-Morgan 1993). Further, behavioral research might be done that anticipates the use of the technology, e.g., user interface design. Survey research done at this stage can only be exploratory about what a user might want or not want, because the technology has not been deployed in real-world settings at this stage.

Emerging

Technologies at the emerging level are being placed in application environments for the first time and thus are "emerging" out of the laboratories. There is commercialization by vendors, and there are pilots and deployments by industry leaders. However, the technology is first-generation. Because the technology and its underlying models have not stabilized, design science developments by academics may contribute to the overall development of the technology. Further, design science researchers can facilitate organizational adoption with further developments in the technology.

It is at this stage in a technology's maturity that researchers and implementers can begin to see what is going right with applications and what is going wrong. Case studies might be used to capture some of those characteristics to better understand the situation of the technology in orga-

TABLE 2
Adopter Categories

Adopter Category	Key Characteristics	Role
Innovators	Venturesome, eager to try new ideas. Communication patterns among innovators are common.	Launches new idea in the social system by importing the innovation from outside system.
Early Adopters	Respectable, has the greatest degree of opinion leadership. The people to check with before using a new idea.	Decrease uncertainty about an idea by adopting it and then conveying an evaluation to near peers.
Early Majority	Deliberate, adopt just before the average. Interact with peers, but not in a leadership position.	Provide deliberate willingness in adopting innovations, but not lead.
Late Majority	Skeptical, adopt just after the average. Innovations are approached with skeptical and cautious air.	Their scarce resources mean that almost all of the uncertainty about an idea must be removed before they adopt it.
Laggards	Traditional, they possess no opinion leadership. Their point of reference is in the past. When laggards adopt, the innovation may have already been superseded.	Last to adopt an innovation.

Source: Rogers (1983), pp. 247–251.

nizations, as individual firms implement the technology (e.g., Sviokla and Keil 1988). Further, surveys or interviews with experts, vendors, and industry leaders can begin to understand what is or is not working as the technology is introduced into organizations. At this stage, vendors may be reaching out to academics to help with the technology diffusion. As a result, some researchers might develop prototypes or pilot implementations themselves to study the technology as situated in organizations (Barker and O'Connor 1989).

As technologies move from embryonic to emerging (and even into later) stages, issues other than the functionality of the technology become apparent and important. For example, as the technology is placed into organizational settings, related issues such as security become important. For example, as expert systems emerged from the laboratories, O'Leary (1990) analyzed how security would become an important part of such systems if they were accepted into organizations. Research investigating the consequences—anticipated or unanticipated—of the new technology might be initiated at this and later stages as the technology is better understood.

At this stage, data can be gathered from organizational settings for empirical research (O'Leary and Turban 1987). However, the data is of limited application because the sample of data is biased, for a number of reasons: the technology is of the first generation, the number of adopters is small, adopters need substantial resources because the technology has a high price, and the technology often must be customized to meet user needs.

Behavioral research may be used to find limitations or strengths in technology use. For example, behavioral research can help understand a technology's limitations from the user's or manager's perspective and drive change to the second generation.

TABLE 3
Strategic Technologies 2004–2008

2004	2005	2006	2007	2008
Instant Messaging	*Instant Messaging*	*Virtualization*	Open Source	Green IT
Real-Time Data Warehousing	*Wider Use of WLANs*	*Grid Computing*	*Virtualization*	Unified Communications
Wireless LANS	Taxonomies	*Service Oriented Business Applications*	*Service Registries and Repositories*	*Business Process Modeling*
Web Services	*IP Telephony*	Pervasive Computing	*Business Process Management Suites*	Metadata Management
Network Systems Management	Software Treated as a Service	OLED/LEP Technologies	Enterprise Information Management	*Virtualization 2.0*
IP Telephony	Static and Unshared Island, Real-Time Enterprise (RTE) Infrastructure	*Location Aware Services (e.g., RFID)*	Ubiquitous Computing	Mash-Ups and Composite Apps
Utility Computing	Utility Computing	Linux	Information Access	Web Platform and WOA
Grid Computing	*Grid*	Desktop Search	Web 2.0 Ajax Rich Clients	Computing Fabric
Network Security Technologies	*Network Security Convergence*	Micro-commerce	Web 2.0 Mash-Up Composite Model	Real World Web
RFID Tags	*RFID Tags*	*Instant Messaging*	Communities and Collective Intelligence	Social Software

Compiled November 2008.
Technologies in italics occur more than one year.

Adolescent

Since the technology is now in its second generation, there are fewer opportunities to address design science issues. However, case studies are likely to be important as leading firms struggle to implement the technology. Since the technology is now in its second generation, the technology is beginning to stabilize. Further, organizations are gaining experience with the technology so that best practices are beginning to emerge. Accordingly, research using case studies or surveys on "things gone right" and "things gone wrong" is likely to find its way into the literature and the classroom. For example, Barker and O'Connor (1989) investigated the use of expert systems at Digital Equipment, providing insights into what was working and what were some key problems.

As firms begin to adopt the technology, opinion studies become less interesting since there are actual settings in which the technology is being implemented (O'Leary 2002). However, as firms adopt the technology, impact studies about the actual effect of the technology gather interest. Further, survey research about the use of the technology can be developed since some firms actually are implementing the technology.

Sample bias using empirical research can emerge at this step. Some firms may be using different (either first or second) generations of the technology. For example, the adoption of RFID by Metro (Ton et al. 2005) requires choosing which generation of RFID chips is to be used. Thus, empirical findings about RFID and other technologies may be driven by the different versions of the technologies actually used, as well as by the firms using them, as discussed below. Further, the coexistence of multiple generations may confound and camouflage results.

Again, behavioral research may drive a better understanding of the strengths and weaknesses of technology usage. Behavioral research can be an important source of information to drive change in technology to the third generation, introduced as the technology goes early mainstream.

Early Mainstream

As applications go mainstream, unbiased sample empirical research that relates to organizational adoption becomes more feasible, because a larger sample of firms has now adopted the technology. As a result, it is at this stage that large-scale empirical analysis can begin to analyze firm characteristics. However, design science and modeling issues become less important, as many of the major problems have already been addressed in the third generation of products. Similarly, case studies are of less interest because a number of organizations have already adopted the technology. The quality of opinion data is overridden by actual experience with the technology (e.g., O'Leary 2002). Behavioral research that needs mature artifacts can now be developed since the third generation of products exists (e.g., Arnold et al. 2006).

Mature Mainstream

Similar to early mainstream, in the mature mainstream, important research issues associated with technology adoption and diffusion can be addressed using empirical research, as researchers can follow the flow of adoption across firms and industries. It is at this stage that full empirical analysis of unbiased samples of accounting and stock market data is likely to be feasible. On the other hand, design science applications generally are too late, unless they push the technology (or a portion of it) back in the maturity curve through new developments. Case studies are no longer of much interest, because the technology is already implemented in a number of environments.

Behavioral research can be used at this stage. In particular, behavioral research that employs fully developed artifacts can be used. For example, Arnold et al. (2006) analyzed an expert system that probably would be categorized as early or mature mainstream. Their research likely could not be done until an artifact that was sufficiently developed could be investigated.

Legacy

As systems move into legacy environments there are a large number of examples of the technology, but the technology is so widespread that few "secrets" of its use exist. Design science, cases, opinion, surveys, etc., are not of general interest, since most issues have been addressed. Legacy technologies are well accepted and widely dispersed. Unfortunately, from an information systems perspective, so-called legacy systems have received only limited attention (e.g., Bisbal et al. 1999).

At times, the need to fix legacy systems has generated additional research concerns. For example, with the year 2000 problem, substantial attention was devoted to legacy software. As firms make additional applications available online, potentially including legacy applications, issues of the security of legacy applications may become increasingly important. In general, legacy systems can provide a large sample; because of the systems' legacy status, firms are less likely to be concerned about the disclosure of value-creating capabilities. As a result, reasonable samples of firms conceivably could be generated for empirical research. Unfortunately, there is likely to be only limited interest in studies about legacy systems. However, as we can see from the changing maturity levels, "Today's emerging technology is tomorrow's legacy technology."

Obsolete

As technologies move out of the legacy category, they become obsolete. A life cycle analysis leads to an interesting finding that apparently little research (AIS or management information systems) is done on technology at this stage. However, it would appear that there are important research questions that can be addressed. For example, understanding what makes a technology "obsolete" might be used to predict when a technology will become obsolete. In particular, what signals can suggest that a technology is no longer going to be used? Is it lack of support by a vendor that ultimately categorizes a technology as obsolete?

Applying to AIS Research

Different methodologies and corresponding research questions can be addressed at different stages of a technology. For example, at the embryonic stage, design science activities, such as the development of models, software, and hardware, are likely to drive the research, since there is limited descriptive data about how the technology works. At the embryonic stage, design science approaches, such as prototyping or modeling, can be the primary tools. Further, at the embryonic stage, expert opinion about the technology or its use is likely to be sought out.

At the emerging and adolescent stages, there is likely to be a focus on case studies that can generate information about best practices, things gone right, and things gone wrong. Expert opinion may be of interest in the case of emerging issues such as the situation of the technology in organizations. At these stages, empirical research is likely to be generated using biased samples. As an example, technology at the emerging stage is first-generation and is more costly than it will be at later stages. Such "mixes" of technologies may bias away from finding results.

However, as the technology moves into later maturity levels, such as early and mature mainstream, alternative research approaches become feasible and preferred. Movement of a technology into early mainstream and mature mainstream allows researchers to gather larger samples of technology uses and to examine issues such as the impact on stock prices or accounting measures, without biased samples, using empirical archival studies. However, at these stages, design science, case studies, surveys, and opinions are not of general interest.

Particular technology maturity levels are likely to be amenable to particular research questions. For example, Table 4 summarizes some applications to the maturity level framework, focusing on potential research issues and methodologies that match the maturity level information and research issues. Table 5 provides another approach to map maturity level onto accounting application type.

Finally, from a sample perspective, it is likely that the sample of firms at each stage is different. For example, firms involved at the embryonic stage are likely to have different characteristics than firms involved only at the legacy stage. Firms at the embryonic stage are likely to have research and development dollars that can be spent on such activities. Such firms also are likely to be in industries where it may be necessary to be aware of the development of such technologies. Accordingly, more dynamic industries are likely to be involved in the development of a technology at the embryonic stages. From a research perspective, that suggests a potential bias in the sample of firms gathered at particular stages. Accordingly, maturity stage may be a correlated omitted variable that should be accounted for in empirical studies.

TABLE 4

Maturity Levels, Research Issues, and Research Methodologies

Maturity Level	Sample Research Issues	Research Methodologies
Embryonic	What is it? How can I get it to work?	Design Science, Model Development, Prototyping, Expert Opinion
Emerging	How does it work in an organization? What are the benefits of the technology?	Design Science, Prototyping, Case Studies, Survey of Impacts, Benefits of Technology Behavioral Study for Design
Adolescent	Why are firms adopting? What went wrong in implementations?	Case Studies, Limitations of Technology
Early Mainstream	How are organizations adopting to the technology? What is the measurable impact of the technology?	Behavioral Studies of System use, Descriptive Research using Stock Prices or Accounting Measures
Mature Mainstream	What is the measurable impact of the technology?	Descriptive Research using Stock Prices or Accounting Measures
Legacy	Other issues, some not technology related, such project management or updating concerns	Descriptive Research since not a Competitive Advantage
Obsolete	What happened, so we don't do it again?	Case Studies Empirical Analysis

TABLE 5

Maturity Level versus Accounting Type

	Financial	Managerial	Auditing	Tax	Systems
Embryonic					
Emerging					
Adolescent					
Early Mainstream					
Mature Mainstream					
Legacy					
Obsolete					

ADOPTION CURVE: FIRM CHARACTERISTICS AT DIFFERENT STAGES

The adoption curve also has qualitative stages, as seen in Table 2. There has been a substantial literature aimed at understanding the adoption process of technologies and how actors on that curve differ from one another. In this section we examine the characteristics associated with the different categories, including "innovator," "early adopter," "early majority," "late majority," and "laggards."

There are a number of implications about the adoption curve for information systems research. First, where a technology is on the adoption curve indicates something about the number of firms that are available as a sample for research. In the beginning there are few firms available for empirical analysis, while by the end there are substantial numbers of firms.

Second, as discussed in Rogers (1983), Mahler and Rogers (1999), and others, there are *distinct differences between the firms in the five categories* on the adoption curve. For example, as noted in Mahler and Rogers (1999, 730), "Strong relationships exist between innovativeness scores and various indicators of bank size, such as total assets, employees, number of branches, number of subsidiaries, and number of customers." In a range of studies, "size" differentiates firms that fall into different categories, such as "innovators" (Mahajan et al. 1990).

Third, as discussed by Harrison and Waite (2006), *the benefits of adopting a technology* vary significantly by adoption curve category. As a result, the business cases apparently differ based on which category the firm occupies, with innovators generating substantially greater benefits along a range of dimensions. In addition, Pennings and Harianto (1992) found that adoption curve category was dependent, in part, on existing technology infrastructure and prior experience. But they also found size was an important variable.

Applying to IS and AIS Research

In any case, this discussion illustrates that both the number of firms available as data points and the categories of firms on the adoption curve have different characteristics. These are critical findings from a research perspective, since they imply that the findings of any empirical analysis of firms will vary based on which group of firms the research is conducted upon and at what point along the adoption curve the research is done. Further, simply the number of firms using the technology and available as data points will vary based on location in the adoption cycle.

In particular, since the different categories of adopters have different characteristics, such as size, this would suggest that analyses of firms that are innovators or early adopters will not generalize to other categories. For example, innovators and laggards provide different samples of firms, and have not only different characteristics, but also different reasons and strategies for adopting a technology. As a result, we are likely to find different results in terms of the impact of a technology if we use a sample of innovators as compared to a sample of laggards, or some broader base of firms. Accordingly, the results of an analysis on innovators or early adopters likely will not generalize to other groups of firms. As an example, O'Leary and Watkins (1995) investigated general characteristics of firms that had implemented artificial intelligence in internal auditing. Because the results were obtained largely from "innovator" firms in artificial intelligence, it is likely that some of the results generated may not generalize to firms in other parts of the adoption curve.

INTERACTION BETWEEN ADOPTION AND MATURITY CURVES: FIRMS VERSUS TECHNOLOGY

Empirical research depends on analysis of the behavior of large groups of firms at some point in time. As a result, in order to do empirical research, we need to be able to generate large unbiased samples of firms, or recognize that the results are limited to a particular category of user.

The joint interaction between the adoption and maturity curves is useful in identifying the types of firms involved at different technology adoption levels. For example, from Figure 2, we can map the 5 percent adoption and the 20 percent adoption marks to the maturity curve. Qualitatively we can see that roughly 5 percent of the adoptions occur by the time the technology has moved from "embryonic" to "emerging" to "adolescence." Further, 20 percent of the adoption corresponds to having the technology move through "early mainstream." Further, we can map the qualitative categories from adoption and maturity to each other as seen in Table 6 providing a map of the types of firms in the sample at the different portions of the technology life cycle.

Examining the interaction of adoption curves and maturity curves in Table 5 (based on Figures 2 and 3), we notice that particular types of firms are most likely to adopt a technology at a particular point in time. As a result, sampling can result in biased samples. For example, if data is gathered at the time the technology is in the embryonic stage, we are likely to have a sample of "innovator" firms only. Similarly, if the data is gathered at the emerging or adolescent stages, then we will find our sample dominated by innovators and early adopters. Until the early mainstream, we are unlikely to have any balance in our sample. Further, it will not be until a technology enters the mature mainstream that we will have a relatively unbiased sample. Interestingly, even at that time we are not likely to have so-called laggards in our sample, so there are still sample biases.

As seen in Table 6, the adoption and maturity curves are highly but not perfectly correlated. In particular, there can be multiple adopter groups in a maturity group, and adopter groups can appear in multiple maturity categories. For example, "innovators" appear in both the "embryonic" and "emerging" categories, while the "emerging" category has both "innovators" and "early adopters."

EXAMPLE: ERP (ENTERPRISE RESOURCE PLANNING) SYSTEMS

As reported in O'Leary (2000), in 1993, during the early days of client-server computing, the entire ERP market was around $300 *million*. By 2005, SAP, the largest vendor, had revenue of $10.5 *billion* (Maguire 2006).

We can try and map the ERP development to the maturity cycle. Based on O'Leary (2000), ERP was an emerging technology in 1993, since the market was small (less than 5 percent of total adoptions, i.e., adoption percent) and the products were in their first generation. As of 1994 and 1995, a few industry leaders, such as Cisco (Cottelear et al. 1998), had begun to implement ERP software.

In the late 1990s ERP likely was in adolescence. In 1998 Deloitte published a report titled "ERP Second Generation" (Deloitte 1998). As a result, we can assume that at this time the technology was in the second generation. As further evidence, in 2000, Gartner declared, "ERP is dead, long live ERP II" (Bond et al. 2000), drawing a line in the sand indicating the end of one era and the beginning of another. In the same Deloitte (1998) report, the focus was on benefits, i.e., "things gone right." Further, O'Leary (2004), using data from 1999, developed a comparative study to the Deloitte (1998) report.

In the early 2000s there was evidence that ERP had entered the "early mainstream" to "mature

TABLE 6

Integrating Maturity and Adoption Categories
"At what maturity level do different groups adopt a technology?"

	Innovators	Early Adopters	Early Majority	Late Majority	Laggards	Adoption %
Embryonic	x					
Emerging	x	x				
Adolescent		x				5%
Early Mainstream		x	x			20%
Mature Mainstream			x	x		
Legacy				x	x	
Obsolete					x	
Maturity %	2.50%	13.50%	34%	34%	16%	

mainstream" level, since most ERP software had become web-enabled, and the technology entered the third generation. As a result, it was not surprising, if we look back and take note, that there was a criticism of the use of expert opinion, as a research methodology, at a relatively late date in ERP's maturity curve (O'Leary 2002) because actual data existed. By sometime around 2005, it was likely that ERP had entered the mature mainstream level of the maturity cycle.

ERP Cases

In order to further analyze this issue, I have summarized the enterprise resource planning (ERP) systems case studies available from the Harvard collection (Table 7). The very first cases, published in 1995 and 1996, were concerned with processes and ERP systems. This corresponds to issues addressed with emerging and adolescent technologies. The case by Davenport (1995) investigating Heatway, suggests that the relationship between reengineering and ERP systems was not well-understood. Through 1996 and into 1999, the concern was with the classic ERP life cycle of requirements analysis, choice, and implementation, when ERP was in its adolescence and was becoming early mainstream. The limited understanding of the technology is exemplified by Cisco's budget generation and project time estimates, which were found to be relatively unfounded (Cottelear et al. 1998). However, around 2000, the focus shifted to integration between ERP systems and integration of ERP systems with so-called "e-business." Since that time other ERP cases have focused on emerging issues such as upgrading an existing ERP system (e.g., McAfee et al. 2004) or business intelligence. That corresponds to the technology going through early mainstream to mature mainstream, as issues related to how the systems would interface with customers and internal systems were addressed along with issues such as making money with the technology.

ERP Research and the Maturity Cycle

Interestingly, some empirical work on ERP systems was done by a number of authors in the early 2000s. Poston and Grabski (2001) was a groundbreaking study that used data from 1989–1997. As a result, it is possible that their sample was biased to maturities in the embryonic, emerging, or possibly the beginning of adolescence stages. In addition, the firms that they investigated were likely "innovators" or at least "early adopters;" that likelihood could also potentially bias the results. Poston and Grabski (2001) found no improvement in selling, general or administrative, or residual income. An alternative potential explanation from the maturity curve is that the technology will have a high price and be highly customized in general in the emerging stage or not meet user needs. Based on the maturity curve argument, we would anticipate that the cost function changes as the technology moves along the maturity curve. As a result, a more recent sample of firms, associated with third-generation technology, might provide a different set of findings; of course, this is an empirical question.

EXTENSION: CHANGES TO TECHNOLOGIES THROUGH THE MATURITY MODEL

A number of changes can influence technologies and affect their life cycle, resulting in changes to the maturity curve (e.g., Fenn 2007). First, technologies can be embedded in other technologies and cease to function as stand-alone. This seems to be a life cycle aspect of many developments in artificial intelligence (e.g., O'Leary and Watkins 1992). Second, technologies may splinter into other concepts, or other technologies may merge together. For example, knowledge discovery is generally thought to consist of techniques from artificial intelligence and statistics. Third, technologies can become extinct, or at least substantially decrease in apparent use, at any point in the life cycle. Fourth, the audience for a technology can change, also influencing the life cycle. For example, KPMG's knowledge management system was initially aimed only at

TABLE 7

List of ERP Cases

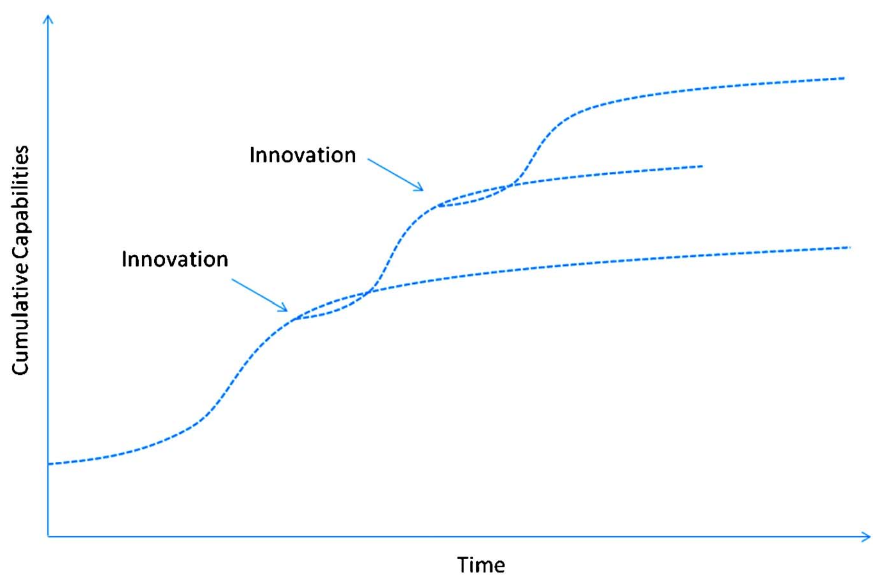
Case	Original Date	Issues	Sector	Issuer
Order Management Reengineering at Heatway	1995	Process Reengineering	Private	Harvard
Vandelay Industries, Inc.	1996	ERP Design, Best Practices and Cost	Private	Harvard
Medalco: The SAP Proposal	1996	ERP Requirements Analysis and System Choice	Private	Ivey
Cisco Systems: Implementing ERP	1998	ERP Requirements Analysis, Choice, and Implementation	Private	Harvard
Timberjack Parts: Packaged Software Selection Project	1998	ERP System Choice and Requirements Analysis	Private	Harvard
Tektronix, Inc.: Global ERP Implementation	1999	ERP Implementation	Private	Harvard
Harley Davidson Motor Company: Enterprise Software Selection	1999	ERP Requirements Analysis and System Choice	Private	Harvard
Rich Con Steel	1999	ERP Choice, Design and Implementation	Private	Harvard
IBM Technology Group	2000	ERP Integration for E-Business	Private	Harvard
Whirlpool Europe	2001	Cost Benefit of ERP Implementation	Private	Harvard
Moore Medical	2001	Peripheral to ERP	Private	Harvard
Extricity, Inc.	2001	ERP Integration for E-Business	Private	Harvard
Digital China Holdings Limited: ERP as a Platform for Building New Capabilities	2002	Relationship between ERP and E-Commerce	Private	Harvard
Business Intelligence Software at Sysco	2004	Getting to ERP Information through Business Intelligence	Private	Harvard
Enterprise IT at Cisco 2004	2004	ERP Upgrade	Private	Harvard
KL World Wide Enterprises, Inc.: Putting Information Technology to Work	2005	E-business, ERP is peripheral	Private	Northeastern
Information Technology at COSCO	2005	Business Impact of ERP	Private	Harvard
Esterline Technologies: Lean Manufacturing	2006	Peripheral to ERP	Private	Harvard
Richter: Information Technology at Hungary's Largest Pharma	2008	3rd Wave of ERP System Issues, Data warehouse, IT Governance	Private	Ivey
Return of the JEBI	2002	ERP and Procurement Integration	Public Sector	HKU
Indian Oil Corporation Limited: Project Manthan	2004	Years into an ERP Implementation	Public Sector	Ivey
The San Diego City Schools	2006	Return on Investment	Public Sector	Kellogg
Enterprise Resource Planning Software: Ongoing Maintenance Cost Benefit Analysis	2006	Determine whether or not to upgrade or change vendors	Public Sector	Ivey

partners (Gladstone and Eccles 1995) and not at lower-level knowledge workers. However, the system ultimately was implemented to focus on providing knowledge to all knowledge workers. Fifth, technologies can go on "hold" or have no recognized specific applications in accounting or auditing. For example, "grid computing" appears to have limited applications for domains such as accounting and auditing.

These many changes can be reflected in the maturity curve. In particular, Gartner's maturity model can be extended to account for major changes in a technology. For example, supply chain capabilities were integrated into enterprise resource planning systems, generating a more complete solution with greater cumulative capabilities. One representation of that rapid increase in capabilities is summarized in Figure 4. That figure captures the following scenario. A technology is going through a normal maturity, gradually gaining new capabilities. However, at some point in time, a large number of capabilities are added simultaneously. This results in a large jump in the capabilities curve.

An interesting issue in Figure 4 is that after each innovation, there is a "dip" in the capabilities. This is consistent with the notions of technology adoption in two ways. First, after any technology adoption there is a time when new technology does not bring improvements, because the full implications of how to use the technology are not clear. When radio frequency identification (RFID, discussed below) was first used in a supply chain environment, some suppliers used a "slap and ship" approach. This meant that they just put the tag on the goods being shipped, but the tag may have been inappropriate (e.g., the wrong generation) or in the wrong spot to be read, etc. As a result, performance did not improve, and costs increased, as firms often relied on paper-based processes to convey the same, duplicate information. Second, as seen with disruptive technologies (Bower and Christensen 1995), innovations often lead to short-term decreases in capabilities.

FIGURE 4
Maturity Curve with Innovations



STRATEGIC TECHNOLOGIES AND AIS

Gartner's "strategic technologies" list provides insights into what Gartner thinks are those technologies that will have a large impact in the next three years or so. As a result, these are likely to be technologies that are in the adolescent or early mainstream stages in the maturity framework. The notion of a strategic technology has limited theoretical structure, generally resulting in a yearly list of particular technologies. A summary of five years of top ten strategic technologies is given in Table 3.

In Table 3, I have italicized those technologies that show up more than once. In some cases the names are exact, while in others they are just very similar (business process management suites versus business process modeling, and grid computing versus grid).

There were roughly 36 different technologies over the five-year period, or about seven new technologies per year. Web services/software as a service lasted the longest, with versions in four different years. Many of the technologies, such as "instant messaging," "virtualization," and "grid computing," apparently do not have substantial uniquely accounting application or concerns. However, this list would appear to provide a starting point for a range of AIS research topics. For example, as discussed later in the paper, business process management appears to provide an important technology for AIS researchers.

Research strategies could include choosing technologies that had appeared on "r" (for some r greater than or equal to 1) different lists of strategic technologies. Alternatively, researchers might limit their selection to the most recent set of technologies, or focus on those that had the clearest accounting and auditing applications.

In AIS, in addition to the technology, researchers need to consider the area of application (Table 5). In particular, that typically means that researchers choose a technology that has a basis in one of the functional areas of accounting, e.g., financial accounting or management accounting (e.g., business process management), but also occurs early in the life of the technology. Generally, AIS researchers would chose a technology for which there is a match to an accounting problem or accounting subdiscipline. Some technologies, such as RFID, at this time do not have well-established or direct accounting ties. As a result, the matching of technology to accounting area becomes a critical research activity early in the life cycle.

Business Process Management

Business process management (BPM) has been given many definitions, including the following definition by Microsoft:

> BPM is the use of an integrated set of key performance indicators that are used to monitor an organizational process in real time. Business process management (BPM) is a management discipline that combines a process-centric and cross-functional approach to improving how organizations achieve their business goals. A BPM solution provides the tools that help make these processes explicit, as well as the functionality to help business managers control and change both manual and automated workflows.

In 2007 business process management was included among the top ten strategic technologies (Gartner 2007). Further, based on Table 3, we can see that BPM shows up as a strategic technology in both of the last two years.

Business process management is a virtual merger of management accounting and accounting information systems. BPM is about managing a process, but it is also about choosing the right key performance indicators—ones that are aligned with strategy and facilitate management of that process. Interestingly, apparently there has been little research by AIS academics in the area of BPM. O'Leary (2009) provides a BPM design science structure for a particular accounting process. Based on the discussion earlier in the paper, we are likely to find some different kinds of research as we move through either the maturity cycle. For example, "things gone right" or "things gone wrong," based on information flows about positive or negative events, are likely to appear as a technology goes into adolescence or even early mainstream. Recently, some case studies have begun to be developed illustrating some of the BPM issues (O'Leary 2009). Behavioral research might examine design issues at first and then move to analysis of implemented systems. As the technology matures, we might see research about how stock market price or accounting measures are influenced by disclosures about BPM, as the sample becomes less biased away from the early adopters.

RFID (Radio Frequency Identification)

RFID is a technology that can be used to uniquely identify objects. We find it multiple times in the top ten strategic technologies over the time period 2004–2008. In 2004, Metro (Ton et al. 2005) and other large retailers began implementing the first generation of RFID. There was much talk about how the technology needed to come down in price, and expenses are a key part of Ton et al. (2005). At that time, few firms had really adopted the technology, and there was limited experience with the technology by firms. Although there was a substantial push by some large retailers, such as Wal-Mart, apparently RFID had not received the attention that had been expected. Thus, RFID fits nicely into the "emerging" technology category. Because the technology is emerging, we would expect case studies like Ton et al. (2005) as a first step. In addition, Ton et al. (2005) begins to provide an analysis of "what went right" and "what went wrong." For example, in 2004, Metro's plan was to have over 250 retail stores, 10 distribution centers, and 100 suppliers using RFID, but at the time of the case there were 13, nine, and 33, respectively. The case allows analysis of why the number of retail stores and suppliers was substantially lower, while the distribution center target was almost reached. Thus, the case study allows analysis of what went right and what went wrong and where the technology fits.

There has been little research on RFID and accounting information systems. O'Leary (2006) discussed a number of potential accounting uses of RFID. For example, RFID could be used to implement specific identification of inventory as a financial reporting strategy. Such specific identification also could be useful in an auditing context as part of inventory analysis. Without RFID, specific identification of individual items would be too costly or not feasible. Geerts and O'Leary (2008) generated a design theory investigation of a database modeling of RFID based on so-called "highly visible supply chains." Until RFID has a larger base of adopters, the amount of data about RFID and the extent to which that data is biased will provide limited analysis.

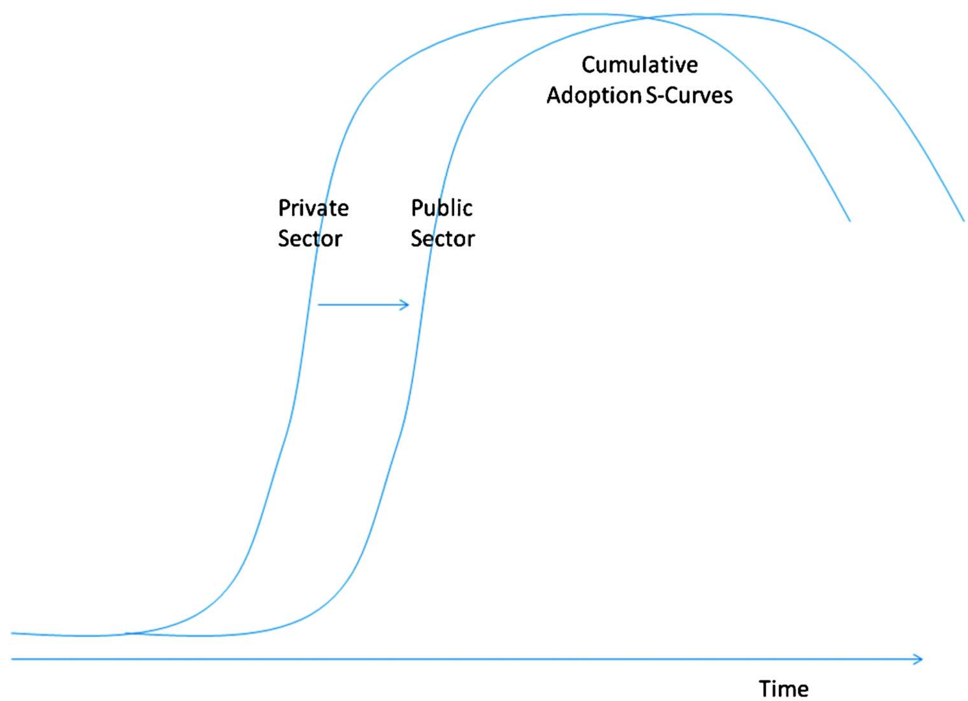
SUMMARY, EXTENSIONS, AND CONTRIBUTIONS

This paper has focused on the maturity curve, the adoption curve, and some of the tools that Gartner has developed to analyze the maturity and adoption of a technology. The paper examined how those tools might be used to understand and anticipate research issues in accounting information systems. It was found that different portions of the maturity curve and the adoption curve have different characteristics and different research opportunities. Accordingly, the interaction between the two curves provides us with insights as to how the sample may be biased at various points in time. Further, the curves provide insight as to when particular types of research, e.g., case studies or design science applications, are likely to occur.

Extensions

There are a number of extensions to this research. First, although the growth curve has been the subject of substantial research, e.g., Rogers (1983) and others, the maturity curve has not received the same level of academic investigation. As a result, future research could investigate

FIGURE 5
Public versus Private Sector Adoption Curves for ERP



characteristics of that curve in more detail. Second, Figure 4 provides an extension to the maturity curve based on adding a large portion of capabilities. However, other versions likely could be developed for other sets of changes in capabilities. Third, although this paper provides numerous examples, additional examples could be elicited and examined. Fourth, this paper argued that empirical research might be using biased samples in a number of settings. Accordingly, an important extension would be to review previous studies and try to determine where some of those biases have slipped in and how the results were affected. Fifth, the issue of biased samples in the analysis of technology may also be applied to the notion of the so-called "productivity paradox" (Grover et al. 1998) (e.g., Pennings and Harianto 1992). For example, technology is more expensive and more brittle at the emerging stage, but less expensive and more flexible at latter stages. As a result, greater productivity gains, at lower costs, are likely later in the maturity and adoption curves.

Further, this same approach can be used outside of technology and refer to ideas and their use. For example, accounting concepts such as activity-based costing or Sarbanes-Oxley likely go through the same maturity and adoption curves, and thus could be studied from the same perspectives, as technology. In the same sense that there are potential sample biases with technologies, there would be potential sample biases in those studies.

Table 6 also provides an additional potential extension. The data gathered there suggests that public and private sectors go through different adoption cycles at different times. As seen in the table, cases about the public sector were addressing some of the same issues that had been addressed a decade earlier in the private sector. One example of a potential relationship between ERP adoption curves is illustrated in Figure 5.

Contributions

Apparently, there has been limited integration of research from firms such as Gartner into academic research. This research used the maturity cycle and level to investigate which research methods can be used at different points in the life cycle of a technology. Accordingly, this research has brought important frameworks that relate to technology diffusion into AIS.

While most previous research focused on the adoption curve (e.g., Rogers 1983), this paper examined the maturity curve. In particular, this paper merged the two concepts of technology maturity and enterprise adoption (e.g., Table 5).

Another contribution of this paper is the notion that the type of research that can be done is tied to where the technology is on the maturity curve and adoption curve, and that, as a result, researchers have different strategies when doing research in technologies. For example, design research is most likely at the embryonic or emerging stages. Further, it is at those same stages that opinion research is most helpful. However, empirical research at those stages will be done using biased samples.

In addition, this paper provides a contribution to potential and existing empirical research. In particular, the adoption and maturity curves help understand the potential biases that can be found in samples of firms when empirical research is undertaken.

REFERENCES

Arnold, V., N. Clark, P. Collier, S. Leech, and S. Sutton. 2006. The differential use and effect of knowledge-based system explanations in novice and expert judgment decisions. *MIS Quarterly* 30: 79.

Baker, C. 2002. Towards increased use of action research in accounting information systems. *Accounting Forum* 24 (4): 366–378.

Baldwin-Morgan, A. 1993. The impact of expert system audit tools on auditing firms in the year 2001: A Delphi investigation. *Journal of Information Systems* 7 (1): 16–34.

Barker, V., and D. O'Connor. 1989. Expert systems for configuration at Digital. *Communications of the ACM* 32 (3): 298–318.

Bisbal, J., D. Lawless, B. Wu, and J. Grimson. 1999. Legacy information systems: Issues and directions. *IEEE Software* (October): 2–10.

Bond, B., Y. Genovese, N. Miklovic, B. Zrimsek, and N. Rayner. 2000. ERP is dead, long live ERP II. Gartner Group research note. October 4. Available at: http://www.pentaprise.de/cms_showpdf..

Bower, J. L., and C. M. Christensen. 1995. Disruptive technologies: Catching the wave. *Harvard Business Review* (January–February): 43–53.

Cottelear, M., R. Austin, and R. Nolan. 1998. *Cisco Systems, Inc.: Implementing ERP*. Harvard Business School Case No. 9-699-022. Boston, MA: Harvard Business Publishing.

Davenport, T. 1995. *Order Management Reengineering at Heatway*. Harvard Business School Case No. 9-996-005. Boston, MA: Harvard Business Publishing.

Deloitte. 1998. *ERP's Second Wave*. New York, NY: Deloitte Consulting.

Fenn, J., and A. Linden. 2005. Gartner's hype cycle special report for 2005. August 5. Available at: http://www.gartner.com/DisplayDocument?doc_cd=130115.

———. 2007. Understanding Gartner's hype cycles, 2007. July 5. Available at: http://www.gartner.com/DisplayDocument?id=509085.

Gartner. 2007. Gartner defines the top ten strategic technologies for 2008. Press release. October 9. Available at: http://www.gartner.com/it/page.jsp?id=530109.

Geerts, G., and D. O'Leary. 2008. *RFID and Inventory in the Supply Chain: An REA and Design Science Approach for Visibility*. Proceedings of the American Accounting Association Annual Meeting. Anaheim, CA.

Gladstone, J., and R. Eccles. 1995. *KPMG Peat Marwick: The Shadow Partner*. Harvard Business School Case No. 9-492-002, Boston, MA: Harvard Business Publishing.

Grover, V., J. Teng, A. Segars, and K. Fielder. 1998. The influence of information technology diffusion and business process change on perceived productivity: The IS executive's perspective. *Information & Management* 34 (3): 141–59.

Harrison, T., and K. Waite. December 2006. A time-based assessment of the influences, uses, and benefits of intermediary website adoption. *Information & Management* 43 (8): 1002–1013.

Hart, P., R. Duda, and M. Einaudi. 1978. Model design in the prospector consultant system for mineral exploration. *Mathematical Geology* 10 (5).

Hevner, A., S. March, J. Park, and S. Ram. March 2004. Design science in information systems research. *Management Information Systems Quarterly* 28 (1): 75–106.

Linden, A., and J. Fenn. 2003. *Understanding Gartner's Hype Cycles*. Gartner Strategic Analysis Report No. *R-1971*. May 30. Stamford, CT: Gartner Inc.

Maguire, J. 2006. The future of ERP. November 15. Available at: http://itmanagement.earthweb.com/erp/article.php/3643966.

Mahajan, V., E. Muller, and R. K. Srivastava. 1990. Determination of adopter categories by using innovation diffusion models. *Journal of Marketing Research* 27 (1): 37–55.

Mahler, A., and E. Rogers. 1999. The diffusion of interactive communication innovations and the critical mass: The adoption of telecommunication services by German banks. *Telecommunications Policy* 23: 719–740.

March, S., and G. Smith. 1995. Design and natural science research in information technology. *Decision Support Systems* 15: 251–266.

McAfee, A., F. W. McFarlan, and A. Wagonfeld. 2004. *Enterprise IT at Cisco (2004)*. Harvard Business School Case No. 9-605-015. Boston, MA: Harvard Business Publishing.

Murthy, U., and C. Wiggins. 1999. A perspective on information systems research. *Journal of Information Systems* 13 (1): 3–6.

O'Leary, D. E., and E. Turban. 1987. The organizational impact of expert systems. *Human Systems Management* 7 (1): 11–19.

———. 1990. Security in expert systems. *IEEE Expert* 5 (3): 59–70.

———, and P. R. Watkins. 1992. Integration of intelligent systems and conventional systems: Requirements for coordinating multiple agents for diagnostic systems. *International Journal of Intelligent Systems in Accounting Finance & Management* 1 (2): 135–150.

———, and P. R. Watkins. 1995. *Expert Systems in Internal Auditing*. New York, NY: Markus Wiener.

———. 2000. *Enterprise Resource Planning Systems*. Cambridge, U.K.: Cambridge University Press.

———. 2002. When and how do we use heterogeneous expert opinion as a basis for research on ERP systems? *Journal of Information Systems* 16: 115–126.

———. 2004. Enterprise resource planning systems: An empirical analysis of benefits. *Journal of Emerging Technologies in Accounting* 1: 63–72.

———. 2006. *Radio Frequency Identification (RFID) and AIS*. Proceedings of the American Accounting Association Annual Meeting, Washington, D.C., August.

———. 2008. Gartner's hype cycle and information system research issues. *International Journal of Accounting Information Systems* 9: 240–252.

———. 2009. Generating and using knowledge for business process management: SYSCO as a case study. *Advances in Business Process Management* (forthcoming).

Pennings, J. M., and F. Harianto. 1992. The diffusion of technological innovation in the commercial banking industry. *Strategic Management Journal* 13: 29–46.

Poston, R., and S. Grabski. 2001. Financial impacts of enterprise resource planning implementations. *International Journal of Accounting Information Systems* 2: 271–294.

Rogers, E. 1983. *Diffusion of Innovations*. New York, NY: The Free Press.

Sutton, S. 2005. The role of AIS research in guiding practice. *International Journal of Accounting Information Systems* (March): 1–4.

Sviokla, J., and M. Keil. 1998. *DuPont's Artificial Intelligence Implementation Strategy* #189036. Boston, MA: Harvard Business School Press.

Ton, Z., V. Dessain, and M. Stachowiak-Joulain. 2005. *RFID at the Metro Group*. Harvard Business School Case No. 9-606-053. Boston, MA: Harvard Business Publishing.