INFORMATION TECHNOLOGY DIFFUSION: A REVIEW OF EMPIRICAL RESEARCH

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ABSTRACT

Innovation diffusion theory provides a useful perspective on one of the most persistently challenging topics in the IT field, namely, how to improve technology assessment, adoption and implementation. For this reason, diffusion is growing in popularity as a reference theory for empirical studies of information technology adoption and diffusion, although no comprehensive review of this body of work has been published to date. This paper presents the results of a critical review of eighteen empirical studies published during the period 1981-1991. Conclusive results were most likely when the adoption context closely matched the contexts in which classical diffusion theory was developed (for example, individual adoption of personal-use technologies) or when researchers extended diffusion theory to account for new factors specific to the IT adoption context under study.

Based on classical diffusion theory and other recent conceptual work, a framework is developed to guide future research in IT diffusion. The framework maps two *classes of technology* (ones that conform closely to classical diffusion assumptions versus ones that do not) against *locus of adoption* (individual versus organizational), resulting in four IT adoption contexts. For each adoption context, variables impacting adoption and diffusion are identified. Additionally, directions for future research are discussed.

1. INTRODUCTION

Innovation diffusion theory provides well developed concepts and a large body of empirical results applicable to the study of technology evaluation, adoption and implementation. Diffusion theory provides tools, both quantitative and qualitative, for assessing the likely rate of diffusion of a technology, and additionally, identifies numerous factors that facilitate or hinder technology adoption and implementation. These factors include characteristics of the technology, characteristics of adopters, and the means by which adopters learn about and are persuaded to adopt the technology (Rogers 1983). It is not surprising, then, that innovation diffusion is becoming an increasingly popular reference theory for empirical studies of information technologies (IT).

As a borrowed theory, innovation diffusion provides the advantage of a rich cumulative tradition. However, when borrowing theory, researchers must take care to ensure that the context to which the theory is being applied matches well with the context in which the theory was developed, or alternatively, to tailor the theory to account for contextual differences. Much of diffusion theory was developed in the context of adopters making *voluntary* decisions to *accept or reject* an innovation based on the benefits they expect to accrue from their own *independent use* of the technology. Yet, adoption of IT may be *encouraged* by management (Leonard-Barton and Deschamps 1988) or even *mandated* (Moore and Benbasat 1991). Adopters, rather than making a binary decision to adopt or reject, may choose differing *levels* of IT use (Bayer and Melone 1989). In addition, the adoption decision of individuals or organizations may depend on the dynamics of community-wide levels of adoption (i.e., whether "critical mass" has been established) because of *network externalities* (Katz and Shapiro 1986; Markus 1987). These sorts of complicating factors are quite common in the context of IT adoption; hence, the opportunities to apply classical diffusion "as is" may be rare indeed.

No critical review exists that focuses specifically on the application of diffusion theory to the adoption of information technologies. This paper presents the results of a review and analysis of eighteen published empirical studies of IT adoption and diffusion from the period 1981 to 1991 with a focus on identifying instances where the adoption context closely matches the context in which classical diffusion theory was developed. To assist in this task, a framework is provided that defines four adoption contexts, one of which closely agrees with the assumptions of classical diffusion and three of which reflect one or more important divergences from classical diffusion assumptions. As would be expected, strong results were most likely to be found in instances where the adoption context was a good match with classical diffusion assumptions, or when additional variables suggested by the adoption context were incorporated into the analysis.

The remaining sections are organized as follows. Section 2 briefly describes the main points of classical diffusion theory. Section 3 describes recent conceptual work relevant to IT diffusion and establishes the foundation for the IT Diffusion Framework presented in section 4. Section 5 presents the results of the empirical review and suggests directions for future research. Finally, section 6 offers some concluding remarks.

2. CLASSICAL DIFFUSION

An innovation is any idea, practice or object that is perceived as new *by the adopter*. Everett Rogers, in a widely cited work (1983), provides a synthesis of over 3,000 previous studies of adoption and diffusion. The results of this synthesis include numerous generalizations about innovation diffusion, i.e., the process by which innovations spread through populations of potential adopters. Among the more well-established generalizations are

1. innovations possess certain characteristics (i.e., relative advantage, compatibility, complexity, trialability and observability) which, as perceived by adopters, determine the ultimate rate and pattern of adoption;

2. some potential adopters are more innovative than others, and can be identified as such by their personal characteristics ("cosmopolitanism," level of education, etc.);

3. the adoption decision unfolds as a series of stages (flowing from knowledge of the innovation through persuasion, decision, implementation and confirmation) and adopters are predisposed toward different kinds of influence (e.g., mass market communication versus word-of-mouth) at different stages;

4. the actions of certain kinds of individuals (opinion leaders and change agents) can accelerate adoption, especially when potential adopters view such individuals as being similar to themselves; and

5. the diffusion process usually starts out slowly among pioneering adopters, reaches "take-off" as a growing community of adopters is established and the effects of peer influence kick-in, and levels off as the population of potential adopters becomes exhausted, thus leading to an S-shaped cumulative adoption curve.

Most diffusion research conforms to one of two distinctive styles: *adopter* studies and *macro diffusion* studies (Attewell 1992). Adopter studies are primarily concerned with understanding differences in adopter "innovativeness" — where innovativeness is usually defined according to time of adoption (early versus late). Macro diffusion researchers are primarily concerned with characterizing the rate and pattern of adoption of a technology across some community of potential adopters; these researchers typically employ mathematical models of the diffusion process. (See Mahajan and Peterson [1985] and Mahajan, Muller and Bass [1990] for a detailed review of the development and application of diffusion models, respectively.)

3. BEYOND CLASSICAL DIFFUSION

The generalizations of classical diffusion were developed mainly by looking at the adoption of innovations by individuals making autonomous choices about whether to adopt personal use innovations that do not require extensive specialized knowledge prior to adoption. More recent research has focused on extending diffusion theory to more complicated adoption scenarios, including

- adoption of innovations by individuals subject to strong *managerial influences* (Leonard-Barton and Deschamps 1988) or by *organizations* as a whole (Kwon and Zmud 1987; Robertson and Gatignon 1986; Rogers 1983, Chapter 10) and

- adoption of special classes of technologies, i.e., those that involve marked *adopter interdependencies* (Katz and Shapiro 1986; Markus 1987) or that impose an exceptional *knowledge burden* on would-be adopters (Attewell 1992; Cohen and Levinthal 1990).

The subsections below briefly describe recent conceptual work relevant to adoption beyond the classical diffusion context.

3.1 Managerial Influences

Individuals rarely have complete autonomy regarding the adoption and use of work place innovations. Management can encourage (or discourage) adoption explicitly through expressed preferences and mandates (Leonard-Barton and Deschamps 1988; Moore and Benbasat 1991), or implicitly through reward systems and incentives (Leonard-Barton 1987b). In addition, immediate supervisors typically control access to the infrastructure supporting adoption, such as training and consulting, and may even control physical access to the hardware and/or software needed to use innovation (Leonard-Barton 1987b; Leonard-Barton and Deschamps 1988). The net result is that studies of individual adoption within organizational settings must either incorporate managerial influences into the analysis or rule them out as a potentially confounding factor.

3.2 Organizational Adoption

While much of classical diffusion theory is still applicable to adoption of innovations by organizations (Van de Ven 1991), modifications and extensions are needed because (a) some classical variables do not map cleanly to the organizational level of analysis (e.g., adopter characteristics), (b) the organizational adoption of an innovation is not typically a binary event but rather one stage in a process that unfolds over time, and (c) the organizational decision process, particularly in the absence of a dominant individual decision maker, frequently involves complex interactions between vested stakeholders.

Rogers provides a useful summary of early research on organizational diffusion (Chapter 10) and notes the potential relevance of such factors as individual leader characteristics (e.g., attitude toward change) and organizational structure (e.g., centralization, formalization, organizational slack). More recently, Kwon and Zmud (1987) and Robertson and Gatignon (1986) have developed more comprehensive frameworks for studying organizational adoption and diffusion. The Kwon and Zmud framework defines five contextual factors (user community characteristics, organizational characteristics, technology characteristics, task characteristics, and environmental factors), each of which may impact any of six stages of IT implementation (initiation, adoption, adaptation, acceptance, routinization, infusion). Robertson and Gatignon propose that a variety of *competitive effects* in the technology consumer's industry (competitive intensity, demand uncertainty, professionalism, cosmopolitanism) and within the technology supplier's industry (level of competitiveness, reputation, R&D allocation, technology standardization) impact the rate and level of diffusion of high technology innovations. The Kwon and Zmud framework is most relevant to studying differences in adopter innovativeness, while Robertson and Gatignon are more concerned with variables affecting the macro diffusion process.

Other potential variables impacting organizational level adoption and diffusion of IT include economic factors, such as trends in pricing (Gurbaxani and Mendelson 1990), and characteristics of the information technology development group and its relationship with client organizations (Ball, Dambolena and Hennessey 1987; Kwon 1990; Zmud, Boynton and Jacobs 1989).

3.3 Adopter Interdependencies

One of the major limitations of classical diffusion is the implicit assumption that individuals are adopting innovations for their own independent use, rather than being part of a larger community of interdependent users. There are at least two qualitatively different ways that a technology can involve important user interdependencies. First, the technology can be subject to *network externalities* (Katz and Shapiro 1986; Markus 1987), which means that the value of use to any single adopter is a function of the size of the network of other users. This concept was originally developed in the context of telephone networks, where the value of subscribership to any individual is directly related to the number of other subscribers that individual can communicate with. Examples of recent IT innovations strongly subject to network externalities include E-mail, voice messaging and computer conferencing.

Second, the use of the technology can be intertwined with *organizational routines* (Nelson and Winter 1982), which means any individual's interaction within the system must fit within some larger organizational process. Perhaps the best example of such a technology is Material Requirements Planning (MRP). MRP systems are intertwined with virtually every aspect of production in manufacturing firms, and hence, any individual's use of the system affects — and is affected by — the pattern of use in the wider community of other users.

When a technology is strongly subject to network externalities, the character of the macro diffusion process can be profoundly affected. Achieving critical mass with a community of users becomes crucial: if critical mass is achieved the innovation is likely to be universally adopted, otherwise, the technology will probably be abandoned (Markus 1987). Markus argues that the distribution of *adoption thresholds*[1] among potential adopters, and the actions of early adopters in particular become especially important to determining whether critical mass will occur. Other determinants of critical mass include *sponsorship* and *adopter expectations*: sponsors can help achieve critical mass by coordinating adoption and subsidizing early adopters; adopter expectations that a technology will eventually be widely adopted can become a self-fulfilling prophecy (Farrell and Saloner 1987; Katz and Shapiro 1986).

For technologies that are intertwined with organizational routines, the *implementation characteristics* of the technology can become important factors impacting adoption and diffusion (Leonard-Barton 1988). Implementation characteristics include the *transferability* (maturity and communicability), *organizational complexity* (number of people and functions affected), and *divisibility* (ability to divide implementation by stages or by sub-populations) of the innovation. At the project level, achieving a proper fit between implementation characteristics and implementation strategies can largely determine adoption success. At the macro-level, innovations with favorable implementation characteristics may be expected to be adopted more easily and diffused more rapidly than those with unfavorable characteristics.

3.4 Knowledge Barriers to Adoption

Some technologies cannot be adopted as a "black box" solution but rather impose a substantial knowledge burden on would be adopters. While classical diffusion focuses on the determinants of a would-be adopter's *willingness* to adopt, in circumstances where knowledge barriers are high the more telling issue can be an adopter's *ability* to adopt. Recent research by Cohen and Levinthal (1990) develops the idea that an organization's innovative capability is determined by its *absorptive capacity,* where absorptive capacity is defined the organization's ability to recognize the value of new information, assimilate it, and apply it to productive ends. An analogous notion of absorptive capacity also exists for individuals. Cohen and Levinthal argue that absorptive capacity is developed over time through prior investments in learning in areas that are closely related to the innovation at hand. The implication is that an important determinant of adopter innovativeness — for both individuals and organizations — is the level of skills and knowledge gained over the course of the adopter's cumulative history of innovation activities.

At the macro diffusion level, Attewell has argued that the diffusion of complex organizational technologies is better understood as a process driven by decreasing *knowledge barriers* than as a process driven by communication and social influence (as per classical diffusion theory). The main implication here is that the rate and pattern of diffusion may depend less on how supply-side institutions signal the innovation (e.g., through communication media) than on the development of *institutions* for lowering knowledge barriers (e.g., service firms and consultants).

4. IT DIFFUSION FRAMEWORK

As described in previous sections, IT diffusion research can diverge from classical diffusion assumptions due to characteristics of the technology (user interdependencies , knowledge barriers) or the locus of adoption (individual versus organizational). The extent of divergence from classical diffusion assumptions provides the basis for a framework for classifying IT diffusion research (see Figure 1). The framework maps two broad *classes of technology* against the *locus of adoption,* resulting in four IT adoption contexts. There are, admittedly, many other ways that adoption context could be classified; however, this classification serves well to distinguish situations where most of the assumptions of classical diffusion are likely to hold (cell 1) from those where important assumptions are likely to be violated (cells 2, 3 and 4).

4.1 Locus of Adoption

The horizontal dimension of the framework refers to the locus of adoption examined by the researcher, i.e., *individual* or *organizational.* Individual adopter studies are usually confined to a single organization. Typical dependent variables here include binary adoption/non-adoption, time of adoption, and frequency of use. Organizational adoption studies look at adoption by large aggregates, such as companies, business units, agencies, or departments. Typical dependent variables here include binary adoption/non-adoption and stage of implementation (e.g., adop-

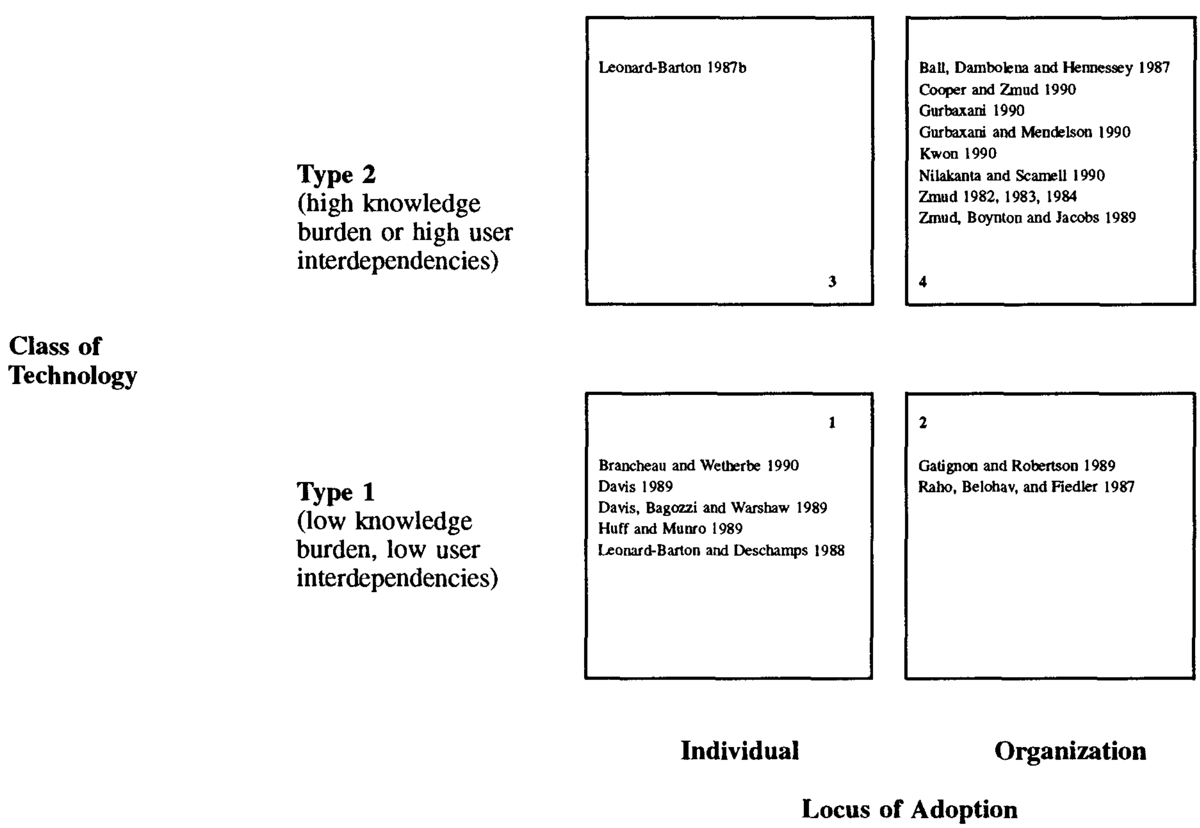

Figure 1. IT Diffusion Research Mapping

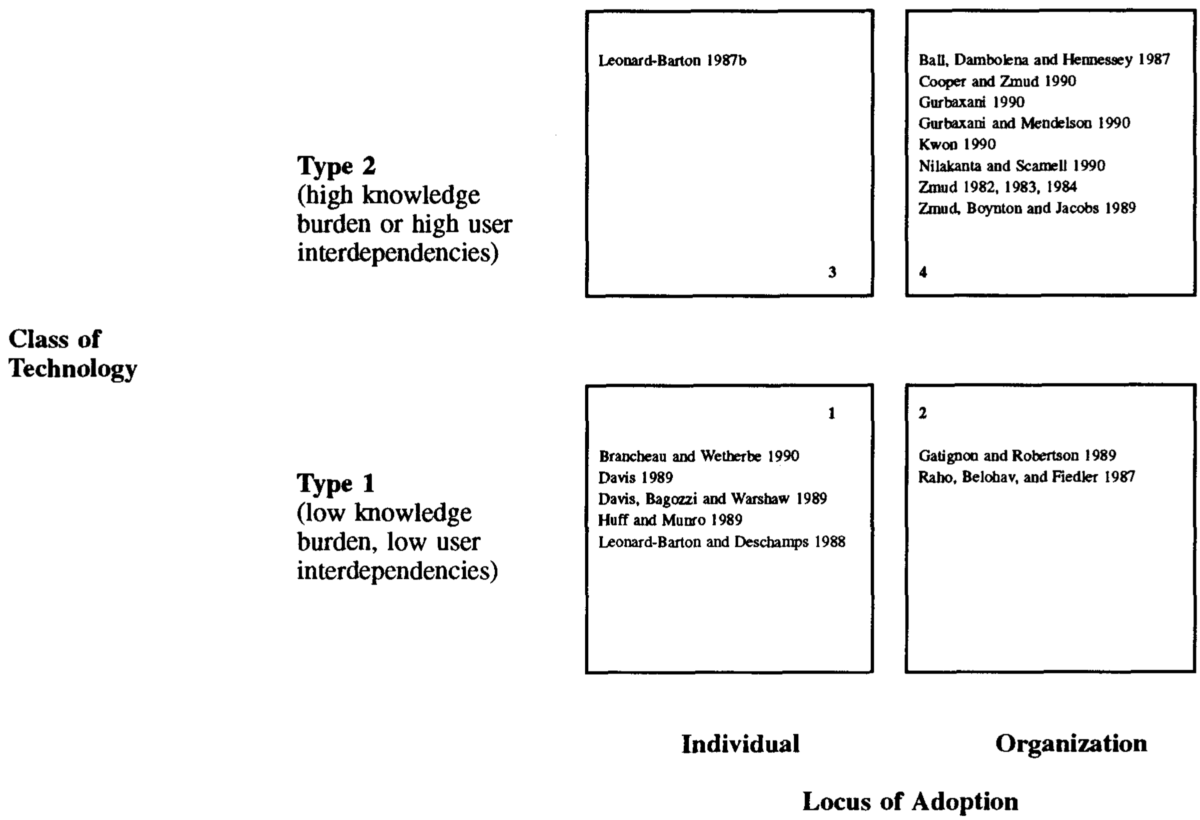

Figure 2. IT Diffusion Research Mapping

tion, adaptation, infusion). Although the adoption of IT by other aggregates (small groups, industries) is certainly possible and well worth future study, in practice, IT diffusion research as reviewed here has been confined exclusively to individuals and organizations.

4.2 Class of Technology

The vertical dimension distinguishes between two classes of IT, which, for the sake of convenience, are labeled Type 1 and Type 2. Type 1 technologies are characterized by a lack of user interdependencies and a lack of a substantial knowledge burden on would-be adopters. Typical Type 1 technologies include single-user hardware (e.g., microcomputers, laptops, portable terminals) and software (e.g., word processing, spreadsheets). Type 2 technologies, by contrast, are characterized by high knowledge barriers (e.g., structured systems analysis, stand-alone CAD drawing systems) or significant user interdependencies (e.g., E-mail, voice mail) or both (e.g., MRP, integrated CAD/CAM).

It is important to note, however, that technologies should be classified on a case by case basis. As Attewell points out, knowledge barriers to adoption for the "same" technology tend to get lower over time. For example, early personal computers imposed a substantial knowledge burden and were only adopted by die-hard hobbyists. Modern window-based personal computers, by contrast, require comparatively little in the way of specialized knowledge prior to adoption and can be adopted by almost anyone. Hence, personal computers circa 1976 would be considered a Type 2 innovation, while personal computers circa 1992 would be considered a Type 1 innovation. In addition, locus of adoption can make a difference. The XSEL expert system studied by Leonard-Barton, for example, was used by most adopters as a "black box" tool to verify computer configurations, suggesting a low knowledge burden to become a proficient user and therefore a Type 1 classification (1987a, p.16). Looking at the organizational level, adoption of an expert system such as XSEL requires the ability to develop and implement the system in the first place, which clearly imposes a severe knowledge burden given the then current state of the technology. Hence, an organizational-level study of diffusion of expert systems would suggest a Type 2 classification.

4.3 Determinants of Adoption and Diffusion

Taken together, the locus of adoption and the class of technology broadly define the adoption context and, hence, the set of potentially relevant variables. For individual adoption of Type 1 technologies (cell 1), classical diffusion provides a majority of the relevant variables, although in some cases managerial influences (as described previously in Section 3.1) will also be key.

Table 1. Empirical Studies of IT Diffusion — Coordinated Use Technologies

Authors	Adoption/Diffusion Phenomenon	Context	Source of Data	Independent Variables	Major Results
Brancheau and Wetherbe 1990 (*Information Systems Research*)	Adoption of ***spreadsheet software*** by individual accountants and managers	1	Questionnaires from 70 accountants and managers in 18 Fortune 1000 firms	***Adopter characteristics*** (age, education, exposure to media, interpersonal communication exposure, opinion leadership, external social participation, etc. ***Communication channel types*** (mass media or interpersonal) ***Communication channel sources*** (external or internal to company	Cumulative adoption follows S-shaped curve using logistic function (R^2 of .996) Early adopters are different than later adopters as predicted per Rogers Mass media channel types/external channel sources more important at the knowledge stage; interpersonal channel types/internal sources more important during persuasion
Davis (1989) (*MIS Quarterly*)	Study 1: Current use of ***mainframe productivity software*** by white-collar workers Study 2: Predicted future use of ***PC graphics software*** by MBA students	1	Study 1: Questionnaires from 112 users within IBM Canada's Development Laboratory Study 2: Questionnaires from 40 students attending a large university	Study 1 and Study 2: ***Perceived technology characteristics*** (perceived usefulness, perceived ease of use)	Study 1: Perceived usefulness and ease of use each highly correlated with self-reported current use Study 2: Perceived usefulness and ease of use each highly correlated with self-reported predicted future use In both studies, ease of use appears to be a causal antecedent of usefulness, with little direct effect on use
Davis, Bargozzi and Warshaw 1989 (*Management Science*)	Current use and actual future use of a ***wordprocessing package*** by MBA students	1	Two waves of questionnaires (14 weeks apart) from 107 MBA students attending a large midwestern university	***Perceived technology characteristics*** (perceived usefulness, perceived ease of use) ***Expectations of salient referents*** ***Attitudes*** ***Behavioral intentions***	Perceived usefulness and ease of use have a significant direct effect on behavioral intentions, over and above their effect transmitted through the mediating attitude construct Behavioral intention to use is significantly related to actual self reported use
Huff and Munro 1989 (*Journal of Information Systems Management*)	Adoption of ***microcomputers*** by individuals	1	Personal interviews with several dozen microcomputer users	***Perceived innovation characteristics*** (relative advantage, compatibility, complexity, trialability, observability)	Anecdotal confirmation that microcomputers diffused quickly because of favorable perceived characteristics
Leonard-Barton and Deschamps 1988 (*Management Science*)	Adoption of an *expert system* by individual sales personnel	1	Telephone survey of 93 salespeople in dozens of sales sites of a multinational computer company	***Personal characteristics*** (innovativeness, job-determined importance, subjective importance of task, task related skill, software use skill, sales performance) ***Managerial influences*** (perceived management support, management urging)	Management was more likely to be viewed as having "suggested" or "required" use of the system by people rating "low" on all personal characteristics (except software use skill)
Gatignon and Robertson 1989 (*Journal of Marketing*)	Adoption of ***laptop computers*** by sales organizations	2	Questionnaires from 125 senior sales officers in US firms	***Adopter industry competitive environment*** (concentration, price intensity, demand uncertainty, communication openness) ***Supply-side factors*** (vertical coordination, supplier incentives) ***Organizational characteristics*** (centralization, selling task complexity) ***Decision maker characteristics*** (information preferences and exposure)	Adoption is associated with high vertical integration and high supplier incentives in the supply industry, and high industry concentration and low competitive price intensity in the adopter industry Decision maker characteristics (preference for negative information and exposure to personal information sources) predict adoption
Raho, Belohlav, and Fiedler 1987 (*MIS Quarterly*)	Infusion of ***personal computers*** industrial firms	2	Questionnaires from 412 (randomly selected) Data Processing Management Association (DPMA) members	***Educational commitment*** (uncommitted, passive, active, strategic as per McFarlan and McKinney)	Phase of diffusion significantly related to level of educational activities
Leonard-Barton 1987b (*Interfaces*)	Adoption of ***structured systems analysis*** (SSA) by individual system developers	3	Survey of 145 programmers, analysts and supervisors in three sites within a natural resources firm	***Perceived innovation characteristics*** (value, feasibility use) ***Organizational influences*** (reward systems, support systems, client preferences) ***Personal characteristics*** (demographic, skills, years of experience)	Clients preferences, adopter attitudes, training in SSA strongly discriminate adopters from non-adopters Years of experience, perceived accessibility of consulting, supervisor desires, and acquaintance with an advocate are moderately discriminating

Authors	Adoption/Diffusion Phenomenon	Context	Source of Data	Independent Variables	Major Results
Ball, Dambolena and Hennessey 1987 (*Data Base*)	Adoption of ***database management systems*** by industrial firms	4	Questionnaires from 24 members of the Boston Chapter of the Society for Information Management	***Organizational characteristics*** (communication effectiveness, number of engineers and scientists in management, etc.) ***IT group characteristics*** (stage in Nolan's lifecycle) ***Information sources*** (journals, advertisements, salespersons, technical staff, etc.)	Organizations with high R&D commitments and a large number of engineers and scientists in management are more likely to be early adopters
Cooper and Zmud 1990 (*Management Science*)	Adoption and infusion of ***MRP systems*** within industrial firms	4	Telephone survey of 52 members of the American Production and Inventory Control Society	***Innovative characteristics*** (task-technology compatibility, technical complexity)	High task-technology compatibility (e.g., continuous manufacturing methods, make-to-stock marketing strategies) and low technological complexity (e.g., fewer parts per bill-of-material and per finished good) positively related to MRP adoption, but not infusion
Gurbaxani 1990 (*Communications of the ACM*)	Cumulative adoption of the ***BITNET computing network*** by universities	4	Quarterly BITNET Network Information Center records and other sources (1981-1988)	Adoption was modeled as a function of the number of previous adopters and time	Three functions were used: Gompertz, logistic, and exponential. The logistic clearly provided the best fit with a R^2 of .996 with significant t-statistics all model parameters
Gurbaxani and Mendelson 1990 (*Information Systems Research*)	Cumulative adoption of ***information technology*** by US firms	4	Archival data on total IT spending by large US firms from industry publications (1960-1987)	Adoption was modeled as a function of the level of previous IT spending and time	Three price-modified functions were used: Gompertz, logistic, and exponential. Confirmed that exponential (price) terms were significant in all three cases (R^2 from .95 to .999), implying that a purely behavioral explanation for IT adoption is incomplete
Kwon 1990 (*ICIS Proceedings*)	Infusion of ***information technology*** within the administrative offices of a southeastern university	4	Field survey of department heads, "opinion leaders" and "MIS coordinators" for 74 administrative offices	***MIS maturity*** (age, applications, equipment) ***MIS climate*** (management support, user involvement, management attitude) ***Work unit size*** ***Network behaviors*** (centrality, sources, intensity, link sources, link intensities)	External communication intensity positively correlated with IT infusion for work groups with a favorable MIS climate
Nilakanta and Scamell 1990 (*Management Science*)	Initiation, adoption and implementation of ***database requirements analysis and logical design tools*** by industrial firms	4	Questionnaires from over 70 lead database designers in 17 Houston area organizations	Characteristics (perceived utility, skills to use, etc.) of 15 ***information sources*** (books, periodicals, etc.) and 13 ***communication channels*** (telephone, library, etc.)	Hypotheses linking characteristics information sources and communication channels to diffusion not supported (only 12 of 90 regression coefficients significant at p-values ranging from .05 to .15)
Zmud 1982 (*Management Science*)	Initiation, adoption and implementation of ***modern software practices*** by aerospace firms and federal agencies	4	Questionnaires from 49 software development managers	***Organizational characteristics*** (centralization, formalization, structural overlays) ***Innovation characteristics*** (administrative versus technical, compatible versus incompatible)	Centralization positively associated with initiation of compatible administrative innovations Formalization positively correlated with adoption of incompatible technical innovations
Zmud 1983 (*MIS Quarterly*)	Adoption of ***modern software practices*** (MSP) by aerospace firms and federal agencies	4	Questionnaires from 49 software development managers	***Information channel availability*** (professional societies, journal subscriptions, internal R&D groups, etc.) ***Organizational characteristics*** (size, professionalism, context)	Confirmed that organizational characteristics mediate the relationship between information channels and adoption of MSP
Zmud 1984 (*Management Science*)	Adoption of ***modern software practices*** (MSP) by aerospace firms and federal agencies	4	Questionnaires from 47 software development managers	***Need-pull*** (complexity of project environment) ***Technology-push*** (innovation recognition) ***Management attitudes*** (receptivity to change, attitude toward MRP)	Group receptivity towards change impacts technical more than administrative innovations; management support leads to more successful innovation; push-pull theory not confirmed
Zmud, Boynton, and Jacobs 1983 (*ICIS Proceedings*)	Penetration of ***information technology*** within industrial firms	4	Questionnaires from IT managers in 132 large organizations and 44 managers in a single high technology firm	***IT management processes*** (various planning and management process such as IBM's BSP) ***IT-client interactions*** (IS manager knowledge of business unit, business manager knowledge of IT	Strongly confirmed that IT-related managerial interactions dominate IT management processes in predicting IT penetration; weakly confirmed that a combination of IT-push and user-pull better predicts IT penetration than either variable alone

For organizational-level adoption (cells 2 and 4), classical diffusion variables are still relevant, although operationalization becomes more complicated insofar as no unitary decision maker exists. For example, it may be necessary to create measures that aggregate individual perceptions. In addition, new variables potentially come into play, such as organizational decision processes (Rogers 1983), organizational characteristics (Kwon 1990), and competitive effects (Robertson and Gatignon 1986) (see Section 3.2).

For adoption of Type 2 technologies (cells 3 and 4), classical diffusion variables may easily become obscured by a plethora additional factors, including critical mass variables (Markus 1987), sponsorship and adopter expectations (Farrell and Saloner 1987), implementation characteristics and strategies (Leonard-Barton 1988), absorptive capacity (Cohen and Levinthal 1990), and institutions for lowering knowledge barriers (Attewell 1992) (see Sections 3.3 and 3.4).

5. REVIEW OF EMPIRICAL RESEARCH ON IT DIFFUSION

Eighteen empirical studies were identified through a manual inspection of titles for all issues of thirteen publication outlets[2] for the period 1981 to 1991. The search included leading journals in the fields of management science and information systems, as well as any journal known by the author to have published at least one article on IT diffusion. A study was included here only if (1) the subject of the study was information technology, (2) the dependent variable(s) were some measure of innovativeness or adoption, and (3) the research looked at adoption by individuals in organizations or organizations as a whole. Similarly to Cooper and Zmud (1990, p. 123), information technology is defined here as any system, product or process whose underlying technology base is composed of computer or communications software or hardware. Figure 2 maps the eighteen studies to the IT Diffusion Framework; Table 1 provides a high-level summary of each study.

The four subsections below use the IT Diffusion Framework as a device to structure a discussion of major results and implications arising from the eighteen studies.

5.1 Individual Adoption of Type 1 Technologies

Five studies examined individual adoption or use of Type 1 technologies. The technologies included a text editor, a wordprocessing package, spreadsheet software, graphics software, personal computers and an expert system (see Table 1). These technologies qualify as independent-use technologies since they were intended to facilitate self-contained tasks performed by individual users. In addition, such technologies usually impose a relatively small knowledge burden, as evidenced by the fact that they typically require only a few hours of training for users to reach a basic level of proficiency.

The generalizations of classical diffusion were strongly supported in the context of individual adoption of Type 1 technologies. Together, the five studies confirmed that

- favorable perceptions of innovation characteristics are positively related to adoption (Davis 1989; Davis, Bagozzi and Warshaw 1989; Huff and Munro 1989);
- adopters are differentially influenced by different information channel types and sources at different adoption decision stages (Brancheau and Wetherbe 1990);
- early adopters/heavy users can be distinguished from later adopters/lighter users according to their personal characteristics (Brancheau and Wetherbe 1990; Leonard-Barton and Deschamps 1988); and
- cumulative adoption follows an S-shaped pattern (Brancheau and Wetherbe 1990).

With the exception of Leonard-Barton and Deschamps (1988), these researchers investigated situations where adopters apparently had wide autonomy in the adoption decision.[3] Interestingly, in the Leonard-Barton and Deschamps study, where managerial influences were expected (because each individual was adopting in the context of a coordinated technology implementation effort), perceived managerial messages were found to influence only some adopters, namely, those that rated "low" on various personal characteristics.

The studies conducted by Davis (1989) and Davis, Bagozzi and Warshaw (1989) are notable for two reasons. First, the theoretical base for this work is Davis' Technology Acceptance Model (TAM) — itself a refinement of Ajzen and Fishbein's (1980) Theory of Reasoned Action (TRA) — rather than diffusion of innovations. However, as Moore and Benbasat point out, there are many parallels between TAM/TRA and diffusion theory. For example, TAM's perceived usefulness and perceived ease of use are essentially the same as diffusion theory's relative advantage and complexity.

Second, the Davis, Bagozzi and Warshaw study is notable as the only example among the adopter studies reviewed here of longitudinal research. This dearth of longitudinal research illustrates one of the major weaknesses not only of the research reviewed here but of the wider body of research on adopter innovativeness, namely, an over-reliance on retrospective measures that leave open questions of causation. With retrospective analysis it is difficult to tell, for example, whether adopters are currently using a technology because of favorable perceived characteristics, or whether favorable perceptions in fact emerged over the course of using the technology.

The results above confirm the value of classical diffusion theory as a description of individual adoption of Type 1 technologies. This suggests that future research in this cell of the framework should concentrate on integrating the various determinants of adoption into more sophisticated models, with correspondingly more sophisticated statistical techniques (e.g., hierarchical regression, path analysis, structural equation modeling).

5.2 Organizational Adoption of Type 1 Technologies

Two studies investigated organizational-level adoption of Type 1 technologies. Gatignon and Robertson (1990) confirmed that adopter industry competitive effects (high concentration, low price intensity) and supplier industry factors (high vertical integration, high supplier incentives) predict adoption of laptop computers by sales organizations. Raho, Belohlav and Fielder (1987) found support for a four phase model of organizational diffusion for personal computing, although their secondary conclusion of a causal relationship from educational activities to phase of diffusion may not be valid; one might just as well argue that phase of diffusion creates a demand for educational activities.

Organizational adoption of Type 1 technologies represents a promising area for future IT diffusion research. This cell of the IT Diffusion Framework provides an opportunity to examine determinants of organizational level adoption and diffusion without the complications introduced by Type 2 technologies (e.g., critical mass effects, unfavorable implementation characteristics). Additional research might serve to distinguish, for example, whether the inconclusive support for classical diffusion variables in many organizational level studies is due to the class of technology rather than the locus of adoption.

Another promising avenue for research here is the role of stages of diffusion. In the Gatignon and Robertson study, a sales organization was considered to have adopted laptops if any sales representatives were using a laptop. This study did not distinguish between stages of diffusion, although, given the comparatively recent commercial availability of industrial-strength laptops, most adopters were probably clustered in an early stage. It might be interesting to replicate this study at a later date when companies are likely to be broadly distributed across different diffusion stages. Then it would be possible to determine whether, as suggested by Cooper and Zmud (1990), the determinants of initial adoption differ from those for later diffusion stages, i.e., adaptation, routinization, and infusion.

5.3 Individual Adoption of Type 2 Technologies

Of the eleven studies of Type 2 technologies, Leonard-Barton's examination of Structured Systems Analysis (SSA) was the only one performed at the individual level of analysis (Leonard-Barton 1987b). The adopters in the Leonard-Barton study were using SSA independently, which implies that such critical mass-related variables as adopter thresholds and early adopter incentives should not be important factors. SSA, however, does involve significant knowledge barriers to adoption. Introductory training for software process technologies such as SSA typically extend over several days and analysts usually require months to reach a basic level of proficiency. Hence, this is a situation where an adopter's ability — not just willingness — to adopt may be a significant determinant of adoption. This may explain why level of industry experience discriminated adopters from non-adopters. Leonard-Barton speculates that experienced analysts were more likely to adopt because they were more capable of grasping the benefits of a tool to create more maintainable code; or in other words, their absorptive capacity with respective to this innovation was higher. Other discriminators included client preferences, adopter attitudes, training, perceived accessibility of consulting, supervisor desires, and acquaintance with an advocate.

The relative lack of attention to individual adoption of Type 2 technologies is unfortunate because, while the organization as a whole makes the initial adoption decision for such technologies, the actions of individual adopters (e.g., how enthusiastically they embrace the innovation) can be expected to have a large impact on the implementation process. This suggests that future research within this adoption context might employ mixed-level research designs. Mixed level research might be used, for example, to link individual acceptance at early stages of implementation to organizational level outcomes at later stages (e.g., implementation success or stage of diffusion reached). Such research might establish diffusion theory as the basis for an "early warning" system for problematic IT implementation projects (Ginzberg 1981).

Another promising avenue for research includes investigations concentrating on technologies that fall on the extreme end of the spectrum regarding adopter interdependencies or knowledge barriers. Research on technologies strongly subject to network externalities, such as E-mail, might concentrate on the role of critical mass variables (e.g., early adopter incentives, level of community wide adoption) on individual adoption decisions; such research would provide a micro-level basis for presumed macro-level outcomes (e.g., distinctive patterns of adoption). Additional research on technologies with high knowledge barriers, such as software process technologies, might confirm the role of absorptive capacity as a strong determinant individual adoption.

5.4 Organizational Adoption of Type 2 Technologies

Ten of eighteen studies examined organizational adoption of Type 2 technologies. These technologies included database management systems (Ball, Dambolena and Hennessey 1987), the BITNET computing network (Gurbaxani 1990), software development process technologies (Nilakanta and Scamell 1990; Zmud 1982, 1983, 1984), and "information technology" (Gurbaxani and Mendelson 1990; Kwon 1990; Zmud, Boynton and Jacobs 1989). Mainframe database management systems are quite complex and are usually intended to support integrated applications with many interdependent users. Software process technologies, as argued previously in the case of SSA, impose a large knowledge burden. BITNET, by contrast, is strongly subject to network externalities. "Information technology," when operationalized at the business unit level within large organizations, is typically dominated by mainframe-based transaction processing and MIS style systems and hence is an interdependent-use technology with a large knowledge burden.

The classical prediction of an S-shaped cumulative adoption curve was confirmed by Gurbaxani for the BITNET computing network. Gurbaxani and Mendelson observed a more intricate pattern of adoption of IT at the national level, with cumulative adoption following an S-curve in the early days of computing followed by an exponential pattern in later years as the effects of decreasing price took over. In the case of BITNET, it is noteworthy that early adopters were subsidized by IBM, who provided funding for centralized network management until a core of over 200 universities had adopted. As mentioned previously, these sorts of early adopter subsidies can be crucial to achieving critical mass in the presence of network externalities.

Another major result consistent with the predictions of classical diffusion theory include Cooper and Zmud's finding that two innovation characteristics, technology complexity and task-technology compatibility, were positively associated with adoption of MRP. In most cases, however, only weak or inconclusive support for classical diffusion predictions were found:

- Information sources and communication channels:
  - Zmud found support for only four of over a hundred expected relationships between information channels and level of adoption, although twelve additional *unexpected relationships* were also found (1983, Table 3)
  - Ball, Dambolena and Hennessey did not confirm that internal information sources are more influential than external source in determining adoption (1987, p. 26)
  - Nilakanta and Scamell found no more significant relationships between information sources/communication channels and adoption than would be expected by pure chance (1990, Tables 5 and 6)
  - Kwon found that only one of five "network behaviors" was a significant predictor of IT infusion (1990, p. 143)
- Organizational characteristics:
  - Zmud confirmed only two of twelve predicted relationships linking centralization and formalization to stage of adoption (1982, Table 3)
  - Ball, Dambolena and Hennessey found that only three of fourteen organizational characteristics were significantly correlated with adoption (1987, p. 23)

One interpretation of these disappointing results is that classical diffusion variables by themselves are unlikely to be strong predictors of adoption and diffusion for Type 2 technologies studied at the organizational level. The implication is that future research on adopter innovativeness should include additional factors suggested by the IT Diffusion Framework, either as independent or control variables. These additional variables might include absorptive capacity, extent of access to (or use of) institutions for lowering knowledge barriers, adopter expectations about whether a technology will reach critical mass, and adopter industry competitive effects. For macro diffusion studies, the technology's implementation characteristics, trends in pricing, degree of sponsorship, and the distribution of adopter thresholds may be key to predicting the extent and rate of diffusion.

A second interpretation of inconclusive results for this context — not mutually exclusive with the first — is that organizational adoption of Type 2 technologies is simply too varied and subtle of a phenomenon to be usefully studied with cross-sectional survey methods. This interpretation suggests that when studying organizational innovation, researchers should consider examining fewer organizations but in greater depth using replicated case study or ethnographic research methods.

6. CONCLUSIONS

Diffusion theory provides a useful perspective on one of the most persistent and challenging topics in the IT field, namely, how to improve technology assessment and implementation. Studies of IT research have produced the strongest results when researchers have examined (1) individual adoption and/or (2) independent-use technologies that impose a comparatively small knowledge burden on would-be adopters. These are instances where the assumptions of classical diffusion research are most likely to hold.

Results were less conclusive in studies of organizational adoption of complex multi-user technologies. This is unfortunate, because many of the most valuable potential applications of diffusion theory fall within this context. Now, more than ever, managers need guidance in assessing new technologies and, if appropriate, formulating an effective adoption strategy. How can organizations be designed to be more innovative? Which of the current slate of advanced technologies — CASE tools, imaging, object-orientation, groupware — will be winners and which will be losers? What can be done to improve the "adoptability" of a technology or, at least, to get advance warning of impending implementation difficulties? Diffusion research — appropriately tailored to the adoption context — potentially holds the key to answering such questions.

7. ACKNOWLEDGMENTS

The author wishes to thank Professors Chris Kemerer, Wanda Orlikowski, and Peter Weill, as well as the anonymous reviewers, for many helpful comments on prior versions of this manuscript.

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9. ENDNOTES

1. An individual's adoption threshold is defined as the number of other previous adopters needed before the individual will consider adoption.

2. The publication outlets were *Management Science, Information Systems Research, Communications of the ACM, MIS Quarterly, ICIS Proceedings, Interfaces, Sloan Management Review, Journal of Information Systems Management, Database, Communication Research, Journal of Marketing, Journal of Marketing Research,* and *Journal of Consumer Research.*

3. In two cases (Davis 1989, Study 2; Davis, Bagozzi and Warshaw 1989), the subjects were MBA students participating in an on-campus experiment. In the other two cases, the adopters were knowledge workers adopting a personal productivity technology. As Brancheau and Wetherbe (1990, p. 117) point out, most knowledge workers have a great degree of autonomy in selecting tools with which to carry out their work.