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Author(s): James C. Brancheau and James C. Wetherbe

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The Adoption of Spreadsheet Software: Testing Innovation Diffusion Theory in the Context of End-User Computing

James C. Brancheau

Graduate School of Business
Management Information Systems
University of Colorado
Boulder, Colorado 80309

James C. Wetherbe

MIS Research Center and
Management Information Systems
University of Minnesota
Minneapolis, Minnesota 55455

Judging by the wealth of problems reported in the literature, information systems (IS) and general managers are not sure how to manage the introduction of new information technology. One step toward providing sound management guidelines is to improve understanding of the social forces which affect the introduction and diffusion process within organizations. This research takes a step toward that goal by examining the validity of innovation diffusion theory within the context of end-user computing. The research involved a field study and historical analysis of the diffusion of spreadsheet software in organizations. To assist in controlling exogenous factors, only finance and accounting departments were studied. Over 500 professionals in 24 business units from 18 large businesses in manufacturing and services participated in the research. Findings supported hypotheses that earlier adopters of spreadsheet software were younger, more highly educated, more attuned to mass media, more involved in interpersonal communication, and more likely to be opinion leaders. Also supported was the hypothesized sigmoidal distribution of adoption over time. Application of the theory was not supported in all areas, however, suggesting that information technology diffusion is different from other diffusion phenomena. Contrary to theory, interpersonal channels of communication were dominant in all phases of adoption decision making. And contrary to their hypothesized role as change agent, IS departments played a minor role in the diffusion process. This was consistent with the observed user-led nature of the phenomenon. Implications for research and practice are discussed.

End-user computing—Innovation diffusion—Adopter characteristics—Emerging information technology—Spreadsheet software

Introduction

End-user computing, i.e., the autonomous use of information technology by knowledge workers outside the information systems department, is an important

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aspect of organizational computing. Research suggests that in the 1990's, information technology will be available to nearly all knowledge workers and will play a dominant role in large organizations (Benjamin 1982, Rockart and Flannery 1983, Roessner 1985, Sprague and McNurlin 1986, Alexander and Connolly 1989, Reed 1989). Continued growth in end-user computing will be fueled by the accelerating development of new information technology. Companies that can foster the adoption of *selected* new technologies may be at an advantage in the years ahead.

From an organizational perspective, the introduction of new information technology within organizations should be facilitated and managed to maximize its benefits and minimize its risks. While failure to establish controls is an evasion of management responsibility, over-control can reduce innovation and productivity. Judging by the wealth of problems reported in the literature (Couger 1986, Gerrity and Rockart 1986, Guimaraes and Ramanujam 1986, Alavi and Weiss 1986), information systems (IS) and general managers are not sure how to manage the diffusion of new information technologies.

Innovation diffusion theory provides a general explanation for the way new ideas and objects spread through a social system over time. The theory was drawn upon heavily in developing the conceptual model for the research (Brancheau 1987). In general, the research asks:

> How well does innovation diffusion theory explain the adoption of end-user information technology by knowledge workers in an organization?

As explained later, the research is operationalized in terms of spreadsheet software diffusion among accounting and finance staff.

The need for the research is underscored by the results of a recent Delphi survey of the most important issues facing IS executives (Brancheau and Wetherbe 1987). IS and general managers ranked "facilitation of organizational learning and use of information technology" and "facilitation and management of end-user computing" among their most critical issues.

Understanding the social forces underlying technology diffusion is critical for effective management of the process. The importance of this research lies in its long-range goal of developing theory-based guidelines for planning and managing the introduction of new end-user information technology. While a single research project cannot achieve this goal, this research makes a contribution toward that goal.

The paper is organized as follows: significant prior research on end-user computing and innovation diffusion is briefly reviewed. Next, major components of the theory are outlined, additional literature is introduced, and research hypotheses are delineated. The research design is described in terms of its context, variables, and data collection procedures. Results are presented and discussed in detail. Finally, conclusions are drawn in terms of key findings and their implications for practice and for research.

Significant Prior Research

In the search to understand the diffusion of information technology, MIS research conducted over the past decade was reviewed. Many articles promoting end-user computing were located. Unfortunately, few rigorous studies have been reported. Most studies have been exploratory in nature. Most data has been collected via semistructured interviews and surveys and used for descriptive purposes. Very little

theory development or testing has been reported (for notable exceptions, see: Henderson and Treacy 1986, Munro et al. 1987, Brown and Bostrom 1989). This study's primary thesis is that research on the management of end-user computing has reached a stage where theory development and testing are critical to the accumulation of new knowledge.

Due to the multidisciplinary nature of the problem, literature from sociology, communication, education, marketing, management, and engineering were also examined. Research from sociology and communication were most useful for providing a comprehensive model of the innovation diffusion process.

Innovation diffusion has been studied in a variety of contexts and from many perspectives. Research on the diffusion of innovations as diverse as hybrid corn (Ryan and Gross 1943), medical drugs (Coleman et al. 1966), and new teaching methods (Carlson 1965) indicates that many innovations diffuse in similar patterns. Rogers' (1971, 1983) synthesis of thousands of such studies resulted in a communication-based theory of innovation diffusion. While the theory developed from contexts outside organizations, Rogers views it as potentially applicable within organizations.

This research is grounded in Rogers' communication-based view of innovation diffusion. While not without its critics (Goss 1979), the Rogers model provides a reasonably comprehensive view of innovation diffusion (Brown 1981). Given this model's focus on the individual adoption process, and given the degree of autonomy that most knowledge workers have in the way they carry out their work, the Rogers model appears to be the most suitable theoretical framework available (Brancheau 1987). Furthermore, the theory's emphasis on communication behavior concurs with a large body of related research in MIS (Zmud 1982, 1983, El Sawy 1985, Huff and Munro 1985, Lee 1986, Moore 1987, Raho et al. 1987, Munro et al. 1987, Conger 1988), in organizational innovation (Zaltman et al. 1973, Meyer and Goes 1988), in technology transfer (Allen 1969, Utterback 1971, Tushman 1977), and in consumer marketing (Assael 1981).

Theory and Hypotheses

The theory frames innovation diffusion as a process driven by uncertainty reduction behavior among potential adopters (Rogers 1983). Innovations (ideas or objects perceived as new) present potential adopters with new means for solving problems and exploiting opportunities. Since it is not known if these new means will be superior to existing means, adoption involves a degree of uncertainty. To cope with this uncertainty, potential adopters are motivated to seek additional information. They often look to near-peers for evaluative information. Thus, diffusion is driven by modeling and imitation of peers and near-peers who have previously adopted a new idea (Bandura 1977).

Innovation diffusion can be defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers 1983). It can be conceptualized at multiple levels of analysis. For example, at the organizational level, the unit of adoption is the organization, while the social system is the organization's external environment. At the individual level, the unit of adoption is the end-user, while the primary social system is the reference organization's internal social environment. Within the context of end-user computing, both organizational- and individual-level factors are undoubtedly important. However, since innovation diffusion theory is most highly developed at the

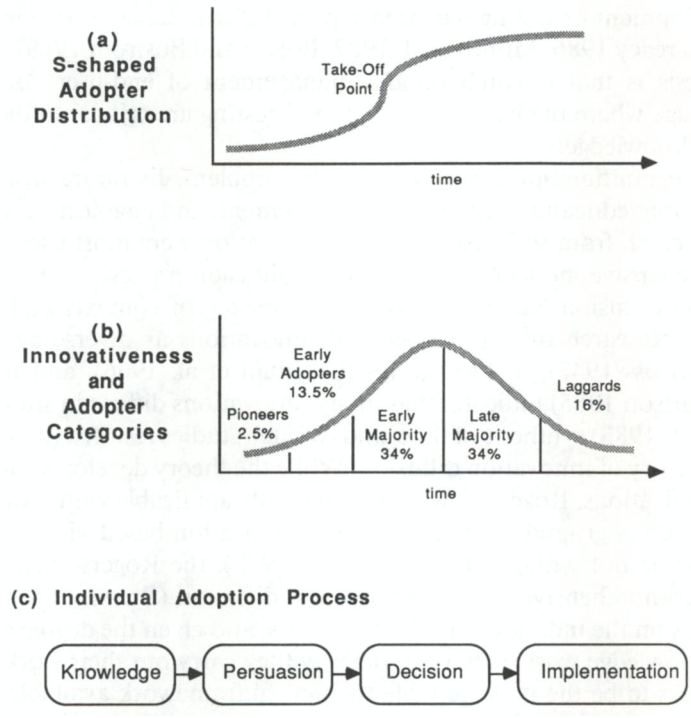

FIGURE 1. Major Components of Innovation Diffusion Theory.

individual level, this research tests the theory there. It was assumed that lack of explanatory power at the individual level would also imply low explanatory power at the less-developed organizational level (exploratory tests at the organizational level are reported in Brancheau 1987).

The theory is best understood in terms of its major components. As illustrated in Figure 1 (a through c), three major components of innovation diffusion theory are: adopter distribution over time, innovativeness and adopter categories, and the individual adoption process.[1]

Adopter Distribution over Time

The rate of diffusion, i.e., rate of adoption, is the relative speed with which the innovation is adopted by members of the social system. Rate of adoption is generally measured as the number of individuals who adopt the innovation in a specified period (where adoption is defined as a binary construct). Thus, it is a numerical indicant of the slope of the diffusion curve over time.

One of the most salient components of the theory relates to a systematic change in the rate of adoption over time. Innovation diffusion research suggests that within a social system, the number of individuals adopting per period of time roughly follows a normal bell-shaped curve (Rogers 1983). Plotted on a cumulative frequency basis, the same data describe a sigmoid or S-shaped curve as shown in Figure 1 (a). Thus, generalizations from innovation diffusion research suggest the following hypothesis (in nonnull form) in regard to the shape of the adopter distribution over time:

[1] Other components of the theory include innovation characteristics, diffusion networks, and opinion leaders. These components have been discussed elsewhere (Brown 1981, Rogers 1983, Brancheau 1987) and are outside the scope of the research reported here.

Hypothesis 1. Cumulative adopter distribution for end-user information technology traces a sigmoidal pattern over time such that more of its variance can be explained using a logistic function that can be explained using a linear function.

This hypothesis follows directly from the communication-based view of innovation diffusion with its emphasis on individual adoption decision making. According to this view, the number of adopters increases slowly at first, due to uncertainty about the innovation. This results in a relatively flat curve. If the innovation is successful, communication channels fill with positive evaluations. After a period of time, a contagion effect takes hold and the number of adopters increase rapidly, resulting in a relatively steep curve. As the market for the innovation saturates, the number of new adopters tapers off and the curve flattens again.

Innovativeness and Adopter Categories

Another major component of the theory involves the concept of innovativeness and adopter categories. Innovativeness is the relative earliness or lateness that an individual adopts an innovation compared to other members of the social system. It is based on the length of time it takes an individual to adopt a particular innovation and is tied directly to the normal adopter distribution discussed above. Rogers (1971) proposed a method of classifying adopters of an innovation according to their relative innovativeness. The classification results from the division of the normal adopter distribution into categories based on its mean and standard deviation. The classification scheme is illustrated in Figure 1 (b), with the five categories labelled as pioneers, early adopters, early majority, late majority, and laggards.

Historically, much of the innovation diffusion research has centered on individual innovativeness and related variables. In particular, it has focused on characteristics of earlier versus later adopters. This is due to the earlier adopters' key role in the diffusion process. Drawing on the work of Rogers (1983) and Assael (1981), several hypotheses (in nonnull form) are offered relating to systematic differences between earlier (both pioneers and early adopters) and later adopters (majority and laggards) of end-user information technology.

When compared with later adopters, earlier adopters:

Hypothesis 2. are younger in age.

Hypothesis 3. have more education.

Hypothesis 4. have greater mass media exposure.

Hypothesis 5. have greater external social participation.

Hypothesis 6. are more externally oriented in terms of communication behavior.

Hypothesis 7. have more contact with the information center staff (or equivalent change agents).

Hypothesis 8. have greater interpersonal communication exposure.

Hypothesis 9. have greater opinion leadership in regard to business-related matters.

Hypothesis 10. have greater opinion leadership in regard to computer-related matters.

Hypothesis 2 states that earlier adopters of information technology are younger. While Rogers (1983) found no difference in age between earlier and later adopters,

others support the age difference (see Assael 1981). Given the short time that end-user information technology has been available and its widespread use in education, earlier adopters can reasonably be expected to be younger in age.

Hypotheses 3–5 follow directly from empirical generalizations developed through Rogers' meta-research. Earlier adopters' higher education may be related to their ability to reduce their perceived uncertainty of adoption. It may also be related to their increased exposure to mass media.

Hypotheses 6–10 are based on the relatively prolific communication behavior of earlier adopters. Among other characteristics, these hypotheses suggest that earlier adopters possess more opinion leadership than later adopters. While this hypothesis follows from Rogers' generalizations, it is not clear whether polymorphic (generalized) or monomorphic (specialized) opinion leadership is intended. Prior research on this question has shown mixed results. Research in marketing (Assael 1981) suggests that while opinion leadership generalizes within product classes (e.g., kitchen appliances) it does not generalize across product classes (e.g., from kitchen appliances to clothing fashion). Similarly, research in technology transfer (Tushman 1977, Tushman and Scanlan 1981) suggests that gatekeeping and boundary spanning activities in certain domains do not generalize to other domains. To the extent that end-user information technology represents a new class of products, opinion leadership from the general business domain may not carry over into this area. However, it is reasonable to expect opinion leadership in one information technology, e.g., spreadsheet software, to generalize to other information technologies.

Individual Adoption Process

The third major component of the theory involves the individual adoption process (referred to as the innovation-decision process by Rogers). Individual adoption is the process through which an individual passes from first knowledge of an innovation, to a decision to adopt or reject, to implementation of this decision. Rogers (1983) suggests that individual adoption is not an instantaneous act, but a process which occurs over time. As shown in Figure 1 (c), individual adoption can be conceptualized as a four-stage process involving knowledge, persuasion, decision, and implementation.[2] The first three stages involve information gathering and attitude formation, and are antecedent to the adoption decision; the fourth stage involves procurement and other activities necessary for putting the innovation to work.

An important implication of the theory is the differentiated use of communication channels across stages of decision making. The communication processes surrounding individual adoption have been studied extensively. Drawing on the work of Coleman et al. (1966) and Rogers (1983), several hypotheses (in nonnull form) are offered regarding the importance of various communication channels in the individual adoption process:

Hypothesis 11. Communication channel type (mass media vs. interpersonal) interacts with adoption decision stage (knowledge vs. persuasion) so that mass media channels are relatively more important at the knowledge stage while interpersonal channels are relatively more important at the persuasion stage.

[2] Rogers included a confirmation stage in his model. However, with regard to information technology, confirmation is better understood as part of the utilization process (Brancheau 1987).

Hypothesis 12. Communication channel source (external vs. internal) interacts with adoption decision stage (knowledge vs. persuasion) such that external channels are relatively more important at the knowledge stage while internal channels are relatively more important at the persuasion stage.

Hypothesis 13. Communication channel type (H13a) and source (H13b) also interact with adopter classification such that earlier adopters are more likely to use mass media/external channels than later adopters, while later adopters are more likely to use interpersonal/internal channels than earlier adopters.

Hypotheses 11 and 12 predict interaction between channel importance and decision stage. Prior research strongly supports these hypotheses outside of organizations (Ryan and Gross 1943, Coleman et al. 1966, Rogers and Kincaid 1981). Thus, while impersonal mass media channels (e.g., trade journals, company newsletters, and vendor literature) may be effective at spreading awareness of information technology, local interpersonal channels are more likely to be effective for forming favorable attitudes.

Research on persuasion also supports these hypotheses (Petty and Cacioppo 1981). For messages containing evaluative information, people generally attribute higher credibility to internal/interpersonal channels than to mass media channels. Because evaluative information is usually difficult to verify, there is always some uncertainty about its accuracy. Thus, people tend to rely on the most credible channels available when forming opinions (persuasion stage) and making adoption decisions (decision stage). In contrast, existence information tends to be more easily verifiable giving it a higher probability of being accurate. Thus, people tend to rely on the more ubiquitous mass media channels for becoming aware of new technology.

Hypothesis 13 suggests that channel importance is moderated by adopter category. This is expected because few people have experience with the innovation during the early stages of diffusion. As a result, little local/interpersonal information is available. Thus, earlier adopters must rely on the less favored channels of mass media for their information. These hypotheses apply to communication from vendor/developers, organization change agents, and adopters both inside and outside the organization.

Research Method

As discussed earlier, this research assumes that innovation diffusion can be usefully conceptualized as a process of individual adoption decision making within organizational constraints. The organizations involved in the research were large businesses in manufacturing and services. The information technology studied was spreadsheet software. The segment of each organization studied was the finance or accounting department. These factors made the context of the research qualitatively different from the context of previous diffusion studies.

Research Context

Studying the diffusion of spreadsheet software offered several advantages. Diffusion was relatively mature, thus permitting an examination of the entire diffusion cycle. Since it occurred rapidly and was a major change from past practices, respondent recall would be less of a problem than if it had occurred over decades. And since spreadsheet software is a relatively discrete product, it was feasible to standardize the adoption construct across companies. In addition, since spreadsheet software has many of the same characteristics as other end-user information technologies, it was

VARIABLE	OPERATIONAL MEASURE
Individual Characteristics	
Age	Fill-in item: Recalculated as age at time of adoption.
Education	Fill-in items: Years of education, highest degree (used as validity check).
Media Exposure	Check-off and fill-in items: Count of media sources used in last six months (journals, books, newspaper, TV news, etc.).
External Participation	Check-off and fill-in items: Count of affiliations with professional associations and attendance at association meetings over past five years.
Change Agent Contact	Multi-item scale: One scaled item for each change agency (normally IS and IC).
Internal Communication	Sociometric choice items: Percent of people in network regularly contacted for advice (at least once per month).
External Communication	Fill-in items: Count of interpersonal contacts outside individual's own department.
Opinion Leadership	Sociometric choice items: Percent of network regularly coming to respondent for advice (at least once per month). Measured separately for business- and computer-related advice.
Advice Seeking	Sociometric choice items: Percent of network regularly sought out by respondent for advice (at least once per month). Measured separately for business- and computer-related advice.
Job Level	Multiple-choice item: (1) clerical/secretarial, (2) professional/technical, (3) supervisory/managerial.

Note: for overall analyses, network data was normalized for effects of different sized networks.

FIGURE 2(*a*). Summary of Research Variables.

reasonable to expect generalization across similar technologies. The possibility of reinvention, e.g., spreadsheets embedded in packaged applications, was minimized through careful wording of research instruments.

Studying adoption in finance and accounting departments offered additional advantages. Since spreadsheet software is broadly applicable for solving numbers-related problems, finance/accounting departments contained a large number of adopters. In addition, since these departments are typically organized into relatively autonomous units, it enhanced isolation of the research sample. Furthermore, since finance/accounting departments follow relatively standardized procedures, it facilitated comparisons across organizations.

Research Variables

The research variables were operationalized through a self-administered questionnaire delivered to each company. Figures 2 (a) and 2 (b) summarize the variables and their operational measures. Variables were selected for their theoretic importance as well as their potential relevance to practice. Individual variables included age, education, media exposure, external participation, and change agent contact. These were measured with a variety of fill-in, check-off, and scaled response items.

Communication behavior variables were measured with sociometric choice questions, such as "Whom do you go to for advice?" and "Who comes to you for advice?" A simplified network analysis was conducted on the results to determine levels of opinion leadership, advice-seeking propensity, and interpersonal communication

VARIABLE	OPERATIONAL MEASURE
Communication Channel Usage	
Channel Type	Multiple-choice items: Classified as *mass media* if newspapers, TV advertisements, magazines, vendor literature, company publications, or company newsletters. Classified *interpersonal* if consultants, vendor personnel, computer specialists, colleagues, teachers, or friends.
Channel Source	Multiple-choice items: Classified *external* if newspapers, TV advertisements, magazines, vendor literature, consultants, vendor personnel, computer specialists at work, teachers outside work, or friends outside work. Classified *internal* if company publications, company newsletters, or colleagues at work.
Outcomes	
Year of Adoption	Fill-in item: First year which spreadsheet was used two weeks or more for work-related purposes (excluding training and demonstration activities).
Innovativeness	Calculated item: Number of years elapsed since adopting spreadsheet software (calculated from year of adoption), e.g., score of 0 for nonadopters, score of 9 for 1979 pioneers.
Adopter Category	Calculated item: Classified into adopter categories (Rogers, 1983) based on date of adoption relative to others in sample: Innovator/Pioneer (first 2.5%) Early Adopter(next 13.5%) Early Majority (next 34%) Late Majority (next 34%) Laggards (final 16%) For analysis across companies, also classified relative to others in same organization.
Adoption Decision Stage	Scaled items: Defined for knowledge, persuasion, and decision stages of individual adoption process. Knowledge involved hearing about spreadsheets for the first time, persuasion stage involved forming an impression, and decision involved deciding to use. Separate questions for each stage.

FIGURE 2(*b*). Summary of Research Variables.

(see Knoke and Kuklinski 1982). This method had advantages over self-report, since it incorporated the viewpoints of the entire network into the measure for each respondent. This helped reduce errors of omission and added objectivity to the measures.

Outcome variables included innovativeness and adopter category (based on year of adoption), and adoption decision stage. Following the tradition of innovation diffusion research, innovativeness was operationalized as the relative earliness an individual adopted the innovation under study.[3] In this research, the year of adoption was defined as the first year that an individual personally used spreadsheet software for work-related tasks for two weeks or more (excluding training and demonstration activities).

[3] Note that the innovativeness construct used here should not be confused with similar constructs which measure an individual's *general* level of innovativeness.

Variables which were controlled in the design included task domain, technology characteristics, organizational actions, and organizational context. Task and technology were controlled by limiting the scope of the research to the adoption of spreadsheet software in the context of finance/accounting. Organizational actions and context were controlled statistically through within-organization analyses.

Data Collection

Data were collected in 1987 through group interviews of key informants and detailed surveys of finance/accounting department staff. Two research instruments were involved. A semi-structured interview guide was used for the group interview. A self-administered questionnaire was used for the finance/accounting department survey.

The group interview was led by one of the researchers. Participants typically included four to six managers and staff (key informants) from information systems and finance/accounting. The first hour of the interview was relatively unstructured and involved asking general questions about the introduction of spreadsheet software in the company. The second hour was highly structured and involved asking questions about organizational actions directed toward managing the introduction and diffusion of spreadsheet software. Interview data were used to tailor the department survey, assess its reliability, and measure organizational actions directed at expanding and controlling spreadsheet diffusion (these data are reported in Brancheau 1987).

The department survey requested current information about personal characteristics and communication behavior. It also requested historical information about jobs held, educational level, and spreadsheet utilization. To improve respondents' recall of historical information, dated "landmarks" for key technological and organizational events were incorporated into the questionnaire (Sudman and Bradburn 1974, Converse and Presser 1986). Graphic time-lines highlighted the dates of key industry events such as the introduction of new personal computers and spreadsheet products, and key organizational events such as mergers, acquisitions, and executive succession. In addition, a year-by-year summary of the respondent's job history was requested to encourage the respondent to think about spreadsheet adoption in concrete terms. Where feasible, variables were measured using multiple item scales. (see appendix for additional details on measurement of variables).

Two organizations were used as pilot sites for developing and testing instruments. In the first, the interview guide and department survey were tested on a small number of users and managers. After revising instruments, a full-scale test was conducted in a second organization. Overall, more than 70 professionals participated in pilot interviews and surveys. Since instruments were revised following each pilot, data from the two tests were not included in the analysis reported here.

Results of the Research

As described earlier, three sets of hypotheses derived from innovation diffusion theory were tested in the research. They covered three of the major implications of the theory: adopter distribution over time, individual differences by innovativeness, and communication channel usage. Before discussing the results of hypothesis tests, it is useful to examine the makeup of the research sample in more detail.

Research Sample

A potential list of participant companies was compiled from the 1987 *Fortune, Forbes,* and *Business Week* top 1000 lists. All companies headquartered near

Minneapolis/St. Paul were considered. Several computer manufacturers were excluded based on the possibility that technology diffusion in those companies might not be representative. A few mid-sized companies were included based on their affiliation with the research cosponsors. In addition, a *Fortune* 1000 company from another area was included to test for differences due to geographic location (no differences were found). The review process produced a list of 36 companies.

Half (50%) of the companies asked to participate agreed to do so despite the heavy commitments involved (two-hour group meeting, survey of entire department, follow-up interviews, etc.). Most companies declining to participate did so because their finance/accounting staff was not available due to peak workloads, e.g., year-end closing, budgeting, etc. Other reasons cited included acquisitions or mergers in progress and company policies against participation. Since the sample was not drawn randomly, there is a possibility of selection bias. A 50% participation rate also leaves open the possibility of nonparticipation bias. While formal analyses were not conducted, there were no apparent differences between participating and nonparticipating companies in terms of size and industry group.

The survey was distributed to managers, supervisors, professionals, technicians, clerks, and secretaries within participating departments. It was distributed to all staff members to avoid biasing the study in favor of current spreadsheet users. Data about nonadopters was considered just as important as data about adopters. Over 300 responses were returned from initial distribution of the survey, yielding a response rate of approximately 70%. Personalized reminder letters netted an additional 85 responses, bringing the response rate to 83% (individual companies ranged from 70 to 100%). Profiles of the companies, departments, and respondents are provided in Figure 3.

Following completion of interviews and surveys, key contacts in each company were asked to provide basic information on nonrespondents to help evaluate potential biases. Nearly all company contacts were able to provide this information through personal knowledge or by calling the nonrespondent. This brought the response rate on the adoption construct to 99% and provided important information for assessing nonresponse bias. In addition, all nonrespondents in one company (five total) were personally asked to fill out the questionnaire one month after they failed to respond to the reminder letter. Information received on these "would-be" nonrespondents provided additional information to assess bias. Follow-up analyses found no significant differences on key explanatory variables.

Hypothesis Tests

Hypotheses were tested in two ways. Tests were conducted overall, across all companies in the sample. These tests assessed the validity of the theory within the finance and accounting professions. Tests were also conducted within each company, with company operating similar to a blocking factor. These tests assessed the validity of the theory within specific organizational subunits.

The way data are reported varies according to the level of test. One of the problems faced within organizations was inadequate sample size. Even though some departments had 40 or more respondents, classification into unequal sized groups seriously eroded the power of the analyses. Consequently, even though results were consistently in the right direction, only a small percentage were statistically significant.

PARTICIPATING COMPANIES
18 Companies, 21 Business Units
By Industry:
57% Manufacturing
43% Services
Annual Revenues:
Ranged from $200 million to $9 billion

PARTICIPATING DEPARTMENTS
By Function:
76% Accounting/Control
24% Finance/Planning

PARTICIPATING INDIVIDUALS
By Job Classification:
38% Supervisory/Managerial
44% Professional/Technical
18% Clerical/Secretarial
By Education:
19% Masters Degree
52% Bachelors Degree
12% Associate Degree
17% No College Degree
By Gender:
51% Male
49% Female

FIGURE 3. Profile of Research Sample.

Thus, for the within analyses, sign tests were used to indicate the probability that the number of tests in the right direction were due to chance.

Adopter Distribution over Time. Hypothesis H1 anticipated a sigmoidal or S-shaped distribution of adoption over time. To test the hypothesis, cumulative spreadsheet adoption across all companies was regressed on time (calendar year of adoption) in two different ways. First, parameters for a linear regression model were computed using the ordinary least squares method. As shown in Figure 4, the linear model fit the data quite well due to the steep slope and truncated nature of the adopter curve (the diffusion cycle was not yet complete). Despite the apparent fit (R^2 = 0.9616), plots of residuals traced a sinuous pattern indicating that the linearity assumption was not tenable (Norusis 1987).

Next, parameters for a nonlinear regression model (logistic function) were computed using iterative least squares procedures (Afifi and Clark 1984). Initial estimates for the model were derived from inspection of scatter plots. Seven iterations were required to obtain the smallest residual sum of squares. Predicted values were computed from the model and correlated with actual values. As hypothesized, the logistic function fit the data better than the linear function. Predicted values correlated with actual values at $r = 0.9998$, yielding an R^2 of 0.9996. Thus, the failure of the linearity assumption combined with the higher R^2 value for the nonlinear model support the sigmoidal distribution hypothesis.

Adopter distributions were also examined within each company. Inspection of residual plots revealed that the linearity assumption was not tenable in 17 of 21 companies. Inspection of adopter distributions suggested they fell into three categories.

Linear: data for four companies supported a linear distribution over time.

S-shaped: data for nine companies supported the hypothesized sigmoidal distribution.

Linked-S: data for eight companies failed the linearity assumption but provided only weak support for the sigmoidal hypothesis. Adopter distribution in these companies appeared to follow dual S-curves, with 1984 a typical breakpoint between curves.

These findings reinforce the notion that a variety of factors influence patterns of adoption over time. Viewing diffusion across differentiated organizations and subunits, specific organizational factors tended to cancel each other out leaving the underlying S-shaped distribution. Within specific organizations, however, a variety of factors combined to affect patterns of adoption. For example, diffusion contexts providing low autonomy due to large numbers of clerical personnel took a variety of forms. One organization placing strict controls on acquisition of personal computer (PC) platforms exhibited a flat and linear distribution, while another organization acquiring a PC for every desk exhibited a vertical step-shaped distribution.

Technological change might have been responsible for primary or secondary takeoff points, resulting in the linked curves observed in the data. Information from interviews suggested that some of the linked S-curves may have resulted from the 1984 announcements of the IBM PC/AT and Apple MacIntosh which provided advanced hardware platforms for spreadsheet software. Slackening hardware acquisition in these companies may have temporarily depressed spreadsheet adoption (briefly flattening the curve). This is an example of the way infrastructure constraints and technological developments can affect patterns of adopter distribution (Brown

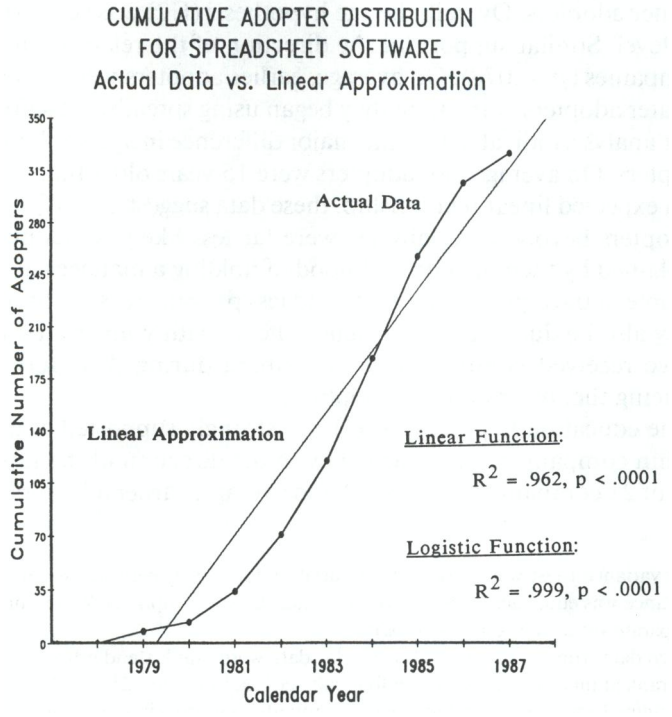

FIGURE 4. Spreadsheet Adopter Distribution.

1981, Brancheau 1987). Thus, while the sigmoidal hypothesis was supported overall, it cannot be assumed that adopter distribution is wholly independent of technological change or specific organizational actions.

Individual Differences by Innovativeness. Hypotheses H2 through H10 anticipated systematic differences between earlier and later adopters of spreadsheet software. Interval and ratio data were analyzed with independent t-test and one-way analysis of variance procedures.[4] Ordinal level data (and other data not meeting normality assumptions) were analyzed with Mann-Whitney U-test nonparametric procedures.

The primary grouping variable was innovativeness. Each respondent was classified as an earlier or later adopter, depending on his or her first use of spreadsheet software. For overall analyses, earlier adopters were those who began to use spreadsheet software before 1983. As framed by the theory, this group represented the first 16% of the adopter distribution. Later adopters were those adopting in 1983 or later, and those who had not yet begun to use spreadsheet software. For within-company analyses, innovativeness was measured relative to other individuals in the same organization. Thus, individuals designated as earlier adopters in one organization (the first 16–25%) may have adopted spreadsheets in 1979–81, while those designated as earlier adopters in another organization may have adopted in 1983–84.

Measures of communication behavior also varied depending on the analysis. For overall analyses, network data were normalized[5] to determine degree of opinion leadership, advice seeking, and interpersonal communication. For within-company analyses, raw network data were utilized. Raw measures provided a more accurate indicator of communication behavior since they were based on a true ratio scale.

As shown in Figure 5, a number of significant differences were found between earlier and later adopters. Overall, the age hypothesis (H2) was supported at the .059 significance level. Similar support for the direction of the relationship was found in 15 of 21 companies ($p = .078$). On average, earlier adopters were two years younger in age than later adopters at the time they began using spreadsheet software. Interestingly, further analysis indicated that the major difference in age was between adopters and nonadopters. On average, nonadopters were 15 years older than adopters. Thus, instead of an expected linear relationship, these data suggest a step function in which potential adopters beyond a certain age were far less likely to adopt. This may be partially explained by their greater likelihood of holding a managerial or supervisory position. People in these positions simply had less pressing reasons to adopt. The step function may also be due to an "experience effect" with younger respondents more likely to have received computer-related training during their formal education, thereby reducing the uncertainty of adoption.

Overall, the education hypothesis (H3) was strongly supported at the 0.002 level. Support within company was also strong, with the direction of the relationship supported in 17 of 21 companies ($p = 0.007$). On average, earlier adopters were found to

[4] The pooled variance t-test was employed for variables for which there was some assurance that the population variance was equal across groups (homoscedasticity assumption). When this assumption was not met, the separate variance t-test was employed.

[5] To normalize data from different sized networks, data were "rank standardized" by converting network scores to ranked quartile scores, i.e., individuals scoring in the top 25% within their network on a measure were assigned a score of 4 for that measure, individuals scoring in the second 25% were assigned a score of 3, and so on.

DIFFERENCES BETWEEN EARLIER AND LATER ADOPTERS

Overall Analysis

Hypothesis/Variable	Mean		Std. Dev.			
	Earlier Adopter	Later Adopter	Earlier Adopter	Later Adopter	*t* Value	Significance Level
Years of Age	28.32	30.33	7.31	10.06	−1.91	0.059*
Years Education	16.18	15.44	1.73	1.84	3.06	0.002***
Media Exposure (number sources)						
—Business	6.29	5.31	3.43	3.83	1.99	0.047**
—Computer	1.87	1.35	2.02	2.38	1.71	0.088*
—Overall	8.16	6.66	4.51	5.32	2.21	0.028**
Participation (number associations & meetings)						
—Business	2.45	2.21	3.37	4.21	0.50	0.619
—Computer	0.19	0.40	0.74	2.03	−1.41	0.159
—Overall	2.64	2.62	3.50	4.85	0.05	0.956
Contact with (frequency)						
—Vendor	0.98	0.72	1.10	1.18	2.71*z*	0.006***
—IS/IC	2.40	2.24	1.57	1.72	.92*z*	0.353
Communication (number people)						
—Internal	21.23	15.83	13.49	11.41	3.44	0.001***
—External	18.38	11.43	25.86	17.29	2.12	0.037**
—Overall	39.38	27.36	35.27	25.20	2.67	0.009***
Opinion Leadership (internal network)						
—Business	2.88	2.41	1.02	1.09	3.30	0.001***
—Computer	2.88	2.31	1.07	1.15	3.85	0.0001***
—Overall	2.98	2.42	0.97	1.09	4.00	0.0001***
Advice Seeking (internal network)						
—Business	2.52	2.52	1.20	1.14	−0.06	0.955
—Computer	2.29	2.56	1.18	1.13	−1.79	0.074*
—Overall	2.56	2.46	1.18	1.11	0.65	0.516
	$N = 68$	$N = 312$	(378 *df*)			

Notes: '*' indicates significance level for *t*-test: *(.10), **(.05), ***(.01). '*z*' indicates Mann-Whitney *z*-score.

FIGURE 5. Individual Differences and Innovativeness.

have about a year more formal education than later adopters. For many adopters, this meant the difference between having a masters instead of a bachelor degree or having a bachelor instead of an associate degree.

Overall, the media exposure hypothesis (H4) was supported at the 0.028 significance level. Support within company was slightly weaker with the direction of the relationship supported in 15 of 21 companies ($p = 0.078$). Exposure to mass media was measured separately for business-related and computer-related media. As shown in Figure 5, earlier adopters were significantly more attuned to both types of media. On average, earlier adopters used one or two more mass media sources per month than later adopters. When accumulated over a long period of time, this represents a major difference in exposure to new ideas.

The external participation hypothesis (H5) was not supported by data from either analysis. Similar to media exposure, external participation (membership in

professional associations and attendance at professional meetings) was measured separately for business-related and computer-related participation. As shown in Figure 5, earlier adopters and later adopters had nearly identical levels of participation. This might be explained by Zmud's (1983) finding that the influence of external participation on the adoption of modern software practices was mediated by the organization's internal environment. He suggests that attendance at certain types of external events is simply too generic to promote innovation within a specific task context. He also suggests that organizational norms favoring change are far more important for stimulating adoption than external participation.

The change agent contact hypothesis (H7) also failed to receive support. In designing the research, it was assumed that the information systems and information center groups (IS/IC) acted as internal change agencies for managing the diffusion of spreadsheet software. In the course of the research, it became apparent that the IS/IC groups may have been the wrong groups to focus on. Qualitative data gathered through interviews suggested that most IS/IC groups did not play an active role in diffusing spreadsheet software in finance and accounting. This is discussed in more detail later.

Overall, the interpersonal communication hypothesis (H8) was strongly supported at the 0.009 level. Support within companies was equally strong with the direction of the relationship supported in 17 of 21 companies ($p = 0.007$). Using self-report data, analyses indicated that in a typical month, earlier adopters talked to nearly 50% more people than later adopters. Even excluding computer-related communication which would bias the results against nonadopters, early adopters were involved in significantly more interpersonal communication than later adopters ($p = 0.038$). Data collection instruments also measured advice-seeking separately from advice-giving. Even though no hypotheses were formulated for advice-seeking, the data are reported in Figure 5. The data suggest that earlier adopters not only give more advice but also seek more advice. Their engagement in communication in both directions helps explain their important role in the diffusion process.

Communication behavior measures were also designed to determine how much respondents talked to people inside their department (internal communication) compared with people from outside their department (external communication). As shown in Figure 5, earlier adopters engaged in both types of communication more frequently than later adopters.

Respondents' degree of external communication was used to test the external orientation hypothesis (H6). Overall, the hypothesis was supported at the 0.037 significance level. The data indicate that in a typical month, earlier adopters talk to over 70% more people outside their department than later adopters. Again, this suggests substantial support for the hypothesis since supervisors and managers (who were strong external communicators) were over-represented as nonadopters. Further support for the external orientation hypothesis is provided by the frequency with which earlier adopters contacted outside vendors on computer-related matters. While neither group contacted vendors very often (each less than once a month), the rank difference on the ordinal scale was significant at the 0.006 level. Support for H6 within company however, was mixed. While early adopters had more contact with computer vendors in 15 of 21 companies ($p = 0.078$), they engaged in more external communication in only 13 of 21 companies (nonsignificant $p = 0.383$).

The opinion leadership hypotheses (H9 and H10) were also supported. Based on normalized network scores, earlier adopters possessed significantly more opinion

leadership on both business-related matters (H9 supported at $p = 0.001$) and computer-related matters (H10 supported at $p = 0.0001$). Support within companies was also strong with 18 of 21 supporting business opinion leadership ($p = .001$) and 17 of 21 supporting computer opinion leadership ($p = 0.007$).

Most communication activity reported by respondents was focused on business-related matters, such as accounting, financial, legal, etc. Earlier adopters had about six more people coming to them for business advice on a regular basis than later adopters. On average, this represents approximately 60% more opinion leadership than found in later adopters. Even though advice-seeking and advice-giving on computer-related matters was significantly less than on business subjects, earlier adopters reported that they had about two more people per month coming to them for advice than later adopters. Even after removing nonadopters from the analysis (a potential source of bias), the difference was significant at the 0.032 level. Given the centrality of the communication behavior and opinion leadership hypotheses to innovation diffusion theory, these findings provide important support for the theory's notion that diffusion for technologies similar to that studied here is driven through interpersonal communication. As discussed later, these findings have important implications for practice.

Communication Channel Usage. Cross-tabulation procedures were used to calculate chi-square statistics to test for independence of the interaction variables. Relationships were further examined to determine if they were in the hypothesized direction. Results from the analyses are presented in Figure 6 and discussed below.

Overall, the channel type/decision stage hypothesis (H11) was supported at the 0.0001 significance level (chi-square = 22.06). Support within company was also strong, with the direction of the relationship supported in 17 of 21 companies ($p = 0.007$). Thus, channel type was not independent of decision stage. Mass media channels were more important to respondents for hearing about spreadsheet software for the first time (15% at the knowledge stage) than they were for forming an impression about the software (4% at the persuasion stage). The opposite effect was observed for interpersonal channels. Respondents found interpersonal channels relatively more important at the persuasion stage (96%) than they did at the knowledge stage (85%). Despite the hypothesized interaction effect, the data strongly indicate that interpersonal channels were favored at both stages of adoption decision making. This is discussed in more detail later.

The communication source/decision stage hypothesis (H12) was also strongly supported at the 0.0001 level (chi-square = 9.10). Support within company was similar with the direction of the relationship supported in 17 of 21 companies ($p = 0.007$). Thus, communication source was not independent of decision stage. External channels (sources in the company's IS/IC group or sources outside the company) were more important to respondents at the knowledge stage (44%) than they were at the persuasion stage (32%). Again, the opposite effect was observed for internal channels where respondents found them relatively more important at the persuasion stage (68%) than they did at the knowledge stage (56%). Paralleling the effects of channel type, the data strongly indicate that internal channels (sources inside the company but not from IS/IC) were favored at both stages of adoption decision making. This is contrary to previous findings in innovation diffusion research and is discussed in more detail later.

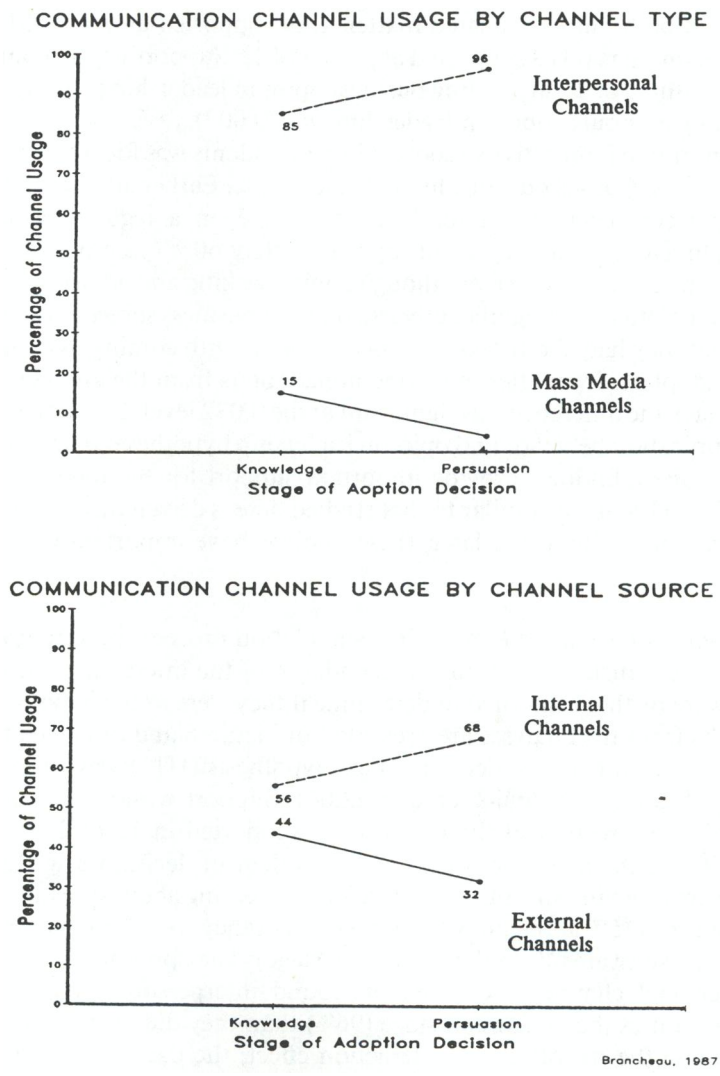

FIGURE 6. Communication Channel Usage by Adoption Decision Stage.

The channel type/adopter classification hypothesis (H13a) was not supported overall (chi-square = 0.00, p = 1.00) or within company (8 of 21, nonsignificant p = 0.383). Interpersonal channels were about as important to earlier adopters as they were to later adopters. Both types of adopters relied on interpersonal channels (93%) far more than mass media channels (7%). Similarly, the communication source/adopter classification hypothesis (H13b) failed to receive support across companies (chi-square = 2.51, p = 0.113), or within company (13 of 21, p = 0.383). Internal channels were favored over external channels by a three-to-one margin by both types of adopters.

Discussion of Results

As summarized in Figure 7, the research provides substantial support for using innovation diffusion theory to explain the individual adoption of end-user

information technology in an organizational context. Most hypotheses derived from theory were supported. Despite this, support for certain aspects of the theory were marginal. In this section, observed relationships are discussed in more detail.

A User-Led Phenomenon

It was apparent from group interviews that spreadsheet diffusion in accounting and finance was a user-led phenomenon. Early adopters were most often professional-level analysts (many of whom had since been promoted to managerial levels). In most cases, they learned about personal computers and spreadsheet software from friends in engineering or research, from auditors and consultants in Big-Eight accounting firms, from teachers at school, or from kids at home. They often brought the new technology into the company without the support or knowledge of the information systems group. Some brought the technology from home, while others procured it as an "office expense."

Unless they had informal (and knowledgeable) contacts within information systems, the pioneers and early adopters had to learn about the new technology on their own. In the interviews, they were often referred to as "self-starters." Most of the early majority (adopting from 1983 to early 1985) continued to rely on themselves and their business colleagues for support. Only in the laggard years (1986–87) did information systems and information center (IS/IC) groups become involved through initial training of new users.

Interview and survey data reinforced the notion that most IS/IC groups did not serve as change agents for their organization. This was reflected in failure of the change-agent hypothesis. Overall, only 3 of 21 IS/IC groups were involved in introducing personal computers and spreadsheet software to their company. As shown in Figure 8, most IS/IC groups did not mount a serious effort (as measured by staff support levels) to manage the diffusion of PC-based technology until 1983–84. The figure clearly shows the lag between the take-off point for spreadsheet adoption and the build-up of support staff.

	HYPOTHESIS/VARIABLE	SUPPORT OVERALL	SUPPORT WITHIN-COMPANY
Adopter Distribution Over Time			
H1	Sigmoidal Distribution	Yes	No
Earlier vs. Later Adopters			
H2	Age	Yes	Yes
H3	Education	Yes	Yes
H4	Media Exposure	Yes	Yes
H5	External Participation	No	No
H6	External Orientation	Yes	Mixed
H7	Change Agent Contact	No	No
H8	Interpersonal Communication	Yes	Yes
H9	Business Opinion Leadership	Yes	Yes
H10	Computer Opinion Leadership	Yes	Yes
Communication Channel Usage			
H11	Type/Stage Interaction	Yes	Yes
H12	Source/Stage Interaction	Yes	Yes
H13a	Type/Adopter Interaction	No	No
H13b	Source/Adopter Interaction	No	No

FIGURE 7. Summary of Findings.

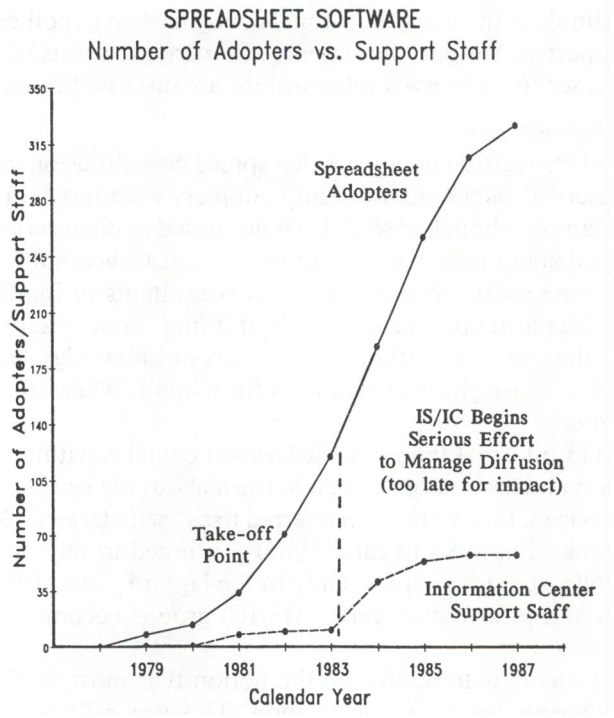

FIGURE 8. Spreadsheet Adopters and IS/IC Support Staff.

Information systems groups acted too little and too late to have a measurable effect. In many companies, IS/IC groups continued to play a minor role in the diffusion process. This is reasonable since theory suggests that after diffusion passes the 16% take-off point, strong network effects make it very difficult to influence from outside the network (Rogers 1983). Group interviews suggested that diffusion of other PC-based technologies in other technology-oriented segments of the organization were also led by users (e.g., research and development, engineering, actuarial, etc.). In these contexts, it appears that the organizations participating in the research were not acting to manage technology diffusion, they were reacting to a user-led phenomenon. One explanation for the user-led nature of the phenomenon is the limited scope of the technology under study. Spreadsheet software's real strength is in supporting personal productivity. Given this focus on individual productivity coupled with its relatively low cost, it is not surprising that individuals with the greatest need for or interest in the technology led the diffusion process.

Interpersonal Channels Dominated

As reported earlier, hypotheses on the interaction between communication channel usage and adoption decision making were partially supported. In addition to interaction effects however, the theory also predicts a main effect in which the use of external and mass media channels is greater than the use of internal and interpersonal channels in the knowledge stage. The data did not support these propositions.

Interpersonal channels dominated all stages of adoption decision making. As shown in Figure 6, interpersonal channels were relied upon by 85% of the potential adopters at the knowledge stage, rising to 96% at the persuasion stage, and (not

shown) 98% at the decision stage. Instead of being dominant at the knowledge stage, mass media channels were relied upon by only 15% of potential adopters. This dropped off to 4% at the persuasion stage and 2% at the decision stage. The relationship between channel source and adoption decision stage followed a similar pattern with internal channels dominating adoption decision making.

Information from group interviews corroborated these findings. Interviews suggested that the diffusion of spreadsheet software in organizations was driven largely through internal/interpersonal channels. Many cases were cited in which diffusion did not take-off in a department until "a seed was planted." The seed referred to was usually a professional-level analyst using spreadsheet software for work-related tasks. Typical comments included "all you had to do was look over Mark's shoulder, the benefits were obvious." And "when I saw how fast Mary was getting the budget reports out, I asked her to show me how to do it."

Prevailing norms in most organizations may necessitate this emphasis on internal/interpersonal channels. Most reward systems indirectly compensate those who pay attention to these channels. Furthermore, the density of internal/interpersonal channels in organizations far exceeds those of social systems in which the theory developed (farming communities, local school districts, intracity medical networks, peasant villages, etc.).

A Closer Look at Individual Differences

To examine hypothesized relationships in more detail, mean values of key variables were plotted by year of adoption. The plots provided additional insight into the theory's strengths and weaknesses. Observed data were plotted and compared with regression lines through the data based on assumptions of positive (or negative) relationships between innovativeness and explanatory variables (Brancheau 1987). For most variables, inspection of the plots confirmed the expected linear relationships. For a few variables however, visual inspection provided additional insight.

As reported, the relationship between external participation and innovativeness was not supported. Further examination suggested that both pioneers (1979–80) and early adopters (1981–83) were outliers in plots of the data but in opposite directions.[6] This coincides with Rogers' (1983) description of these adopter categories. He suggests that "Whereas innovators [pioneers] are cosmopolite, early adopters are localite . . . they are a more integrated part of their local social system." The high level of participation observed for pioneers is also consistent with the engineering management literature. It describes pioneers as "outward-looking technology gatekeepers" (Allen 1967). Further supporting the gatekeeper explanation, the pioneers were also outliers in plots of change agent contact. At the time of the survey, the pioneers' level of contact was significantly greater than that of other adopters (Mann-Whitney U significant at $p = 0.041$). Thus, while IS/IC did not formally influence the diffusion process, informal contacts between IS/IC staff and pioneers did exist.

As shown in Figure 9, business-related opinion leadership appeared to have a nonlinear relationship with innovativeness. In this case, however, the shape of the curve was similar to that predicted by theory (Rogers 1983, p. 262). Theory suggests that the slope of the relationship is positive up to the point at which early adopters

[6] Recall that pioneers and early adopters were lumped together as "earlier adopters" for hypothesis testing.

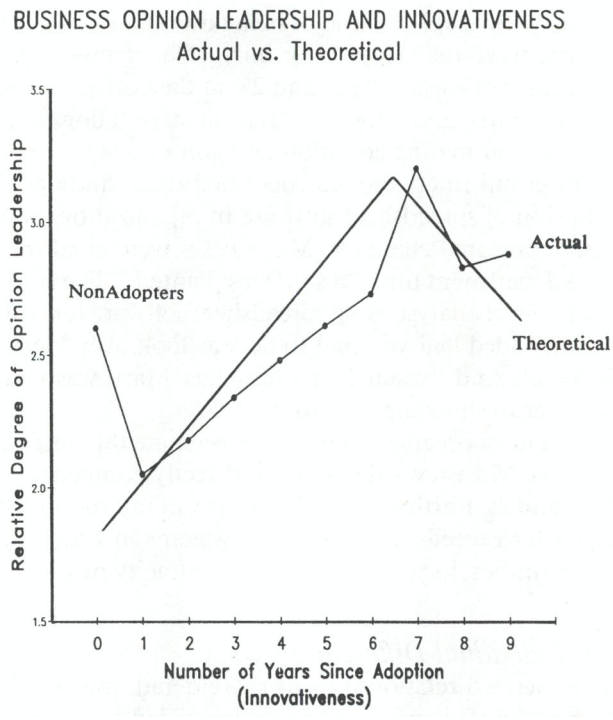

FIGURE 9. Business Opinion Leadership and Innovativeness.

began using the innovation (year 6 in the figure) then negative for pioneer adopters (years 8–9 in the figure). Data on spreadsheet adoption follow this pattern with one exception: nonadopters had substantially more opinion leadership than predicted. This is understandable given that nonadopters were over-represented by managers (chi-square significant at $p = 0.0001$) and thus possessed a certain amount of opinion leadership by virtue of their position. Computer-related opinion leadership closely conformed to the pattern suggested by theory with nonadopters possessing almost no opinion leadership. This is also understandable since managers often have less interest in and need for spreadsheet technology.

Limitations

As is common with research involving organizations, a number of factors could have operated separately or in combination to confound results. The research partially controlled these factors through within-organization analyses. By repeating analyses within each company, many confounding effects were eliminated. In addition, follow-up analyses within industry, function, and size classification yielded equivalent support for the theory. And while specific actions by vendors may have varied across organizations, group interviews verified that none of the participating organizations were used as beta test sites for new spreadsheet software products.

Additional statistical controls were used to test for possible confounding effects from job turnover and job level/position. For example, follow-up analyses of long-tenure employees (respondents working since 1979) remained supportive of most hypotheses although significance levels were reduced due to sample reduction. Follow-up analyses controlling for job level (manager/supervisor, professional/

technical, and secretarial/clerical) were similarly supportive of most hypotheses although strongest support was found within the professional/technical group.

A limitation of the research design was its focus on one information technology at the exclusion of others. This reduces ability to generalize to other classes of information technology. Nevertheless, since spreadsheet software is similar to other information technologies such as word processing, database management, and business graphics, in that they are individually adoptable, support a variety of tasks, and are relatively easy to use, generalization may be justified in terms of existing theory. A similar design limitation was the focus on finance and accounting. Generalization to other functional areas is problematic. Additional research is needed. The lack of control over specific job task was also a limitation. Job task is related to the relative advantage experienced by potential adopters. This undoubtedly affects adoption behavior. While the research controlled for task domain, more refined measures are needed in future research.

The retrospective nature of the study was the most important limitation of the research. Even though several steps were taken to improve respondent recall, it cannot be assumed that individuals had perfect recall of personal events occurring during the study period. Related to this, the ability to draw causal inferences was limited. For example, it is possible that the adoption of spreadsheet software *caused* the current levels of certain variables. Thus, earlier adopters may not have had the same level of media exposure or opinion leadership that they possessed at the time of adoption. These problems are inherent in the research design. The only way to resolve them is to study diffusion over an extended period of time. Given the resources available however, this was not feasible. Fortunately, these limitations are moderated to the extent that communication behavior and contextual variables are relatively stable over time (Albrecht and Ropp 1984). They are further moderated with knowledge that early retrospective studies in other diffusion contexts were later confirmed via longitudinal studies (see Freedman and Takeshita 1969).

Conclusions

Findings supported hypotheses that earlier adopters of spreadsheet software were younger, more highly educated, more attuned to mass media, more involved in interpersonal communication, and more likely to be opinion leaders. Also supported was the hypothesized sigmoidal distribution of adoption over time. Contrary to theory, interpersonal channels of communication were dominant in all phases of adoption decision making. And contrary to their hypothesized role as change agent, IS departments played a minor role in the diffusion process. This was consistent with the observed user-led nature of the phenomenon. These findings have a number of implications for both practice and for research. These are discussed next.

Implications for Practice

Based upon the study's findings about communication channel usage (H11–H12), one message to IS/IC groups and vendors is that mass media channels (newsletters, bulletins, etc.) may have limited effectiveness for making individuals aware of a new information technology, and are rarely effective for persuading a potential user to adopt. By contrast, interpersonal communication should be effective at all stages of adoption decision making. This is consistent with prior research showing that information centers rated as most effective (from user's viewpoint) were the most active in reaching out to users through consulting and training activities (Brancheau and

Wetherbe 1988). IS/IC groups, and others responsible for managing diffusion in organizations, should be aware of their users' communication channel preferences in planning and managing diffusion campaigns.

While the change agent contact hypothesis (H7) was not supported, follow-up analyses suggested that pioneer adopters (the earliest 2–3%) did have significant levels of contact with IS/IC staff. To IS/IC managers, these contacts are potentially valuable for keeping informed of new technologies being examined by gatekeepers across their company. Such advance knowledge can help managers position themselves for action before the contagion effects of the diffusion network take hold (see Brancheau and Wetherbe 1989).

The strong support for the interpersonal communication hypothesis (H8) suggests that early adopters are very important in diffusion. Because they are not too far ahead of the average individual in innovativeness, they can serve as an important role model for many individuals. The early adopters' social connections help them play a boundary spanning role in spreading new ideas across the organization (Tushman 1977, Tushman and Scanlan 1981).

Strong support for the opinion leadership hypotheses (H9–H10) has similar implications. Theory suggests that once diffusion reaches a certain point (estimated at 10–25%), opinion leaders within the organization are far more effective in influencing others to adopt than members of a change agency such as IS/IC. If opinion leaders are identified in advance in key areas of the organization, they can be instrumental in assisting efforts to manage the diffusion process.

Overall, a message to managers is that the social forces underlying technology diffusion are real. They are at least partially measurable and predictable. By improving their understanding of the diffusion process, managers can work with the social forces instead of against them.

Implications for Research

Based on the quantitative results presented above and the subjective judgments formed during hours of interviews, it was clear that innovation diffusion theory did not provide a complete explanation for technology diffusion in organizations. Additional factors should be considered in future research.

First, while the adoption of spreadsheet software in finance and accounting appears to have been led primarily by end users, this cannot be expected to carry over into all technology diffusion contexts. Organizational factors are likely to be more important in contexts involving proactive diffusion management or reduced adoption decision autonomy. Future research could examine the role of technology "scope" in mediating the relative importance of organizational and individual factors. This study's focus on individually adoptable technology undoubtedly led to its strong support for the influence of individual factors. The diffusion of information technologies such as computer assisted systems engineering products (departmental scope) and integrated systems digital networks (organizational scope) can be expected to be influenced by a different mix of individual and organizational factors.

Second, potential adopters strongly favor the use of internal/interpersonal channels of communication. These channels are partially shaped by organizational structures. Thus, an individual's position and job task strongly affect his or her communication behavior. It would be useful to know more about the ways organizational structure affects diffusion networks and opinion leadership. Current theory only

indirectly recognizes the structural effects of position and job task. Given their importance in the end-user computing context, they should be recognized explicitly in future research. This is an area where research on organizational communication may prove very helpful (see Jablin et al. 1987).

Third, within a given organization, substitute technologies may be available which substantially affect the relative advantage provided by a specific information technology. At present, substitute technologies are incorporated into the theory indirectly through the concept of relative advantage. Relative advantage is determined by the fit between new technology and the potential adopters' task environment with respect to other alternatives perceived to be available. Further insight can be gained in future research by explicitly recognizing the role of alternative technologies within the relative advantage construct.

Fourth, rapid technological change is characteristic of the end-user computing context. Most information technology innovations undergo constant improvement. As discussed above, it appeared that rapid change in the hardware environment underlying spreadsheet software may have influenced adopter distributions in some companies. For other information technologies, on-going improvements may have a radical impact on the innovation's relative advantage. Here, explicit recognition in future research might improve understanding of technology diffusion. What is needed is a measure of cost and functionality which is independent of the adoption context. This may be difficult given the current lack of metrics for describing system functionality.

Finally, beyond adoption, understanding information technology diffusion requires understanding of utilization. Utilization is the process an individual passes through as the adoption decision is confirmed and the innovation is put to full use (Brancheau 1987). While many innovations have fixed and narrow uses, the inherent flexibility of information technology makes utilization important for understanding diffusion. While innovation diffusion theory does not provide much guidance for future research in this area, the traditional MIS literature may prove quite helpful (see Trice and Treacy 1988).

Overall, two major points can be made given this initial test of innovation diffusion theory in a new context. First, the theory has proved useful for understanding the social forces involved in individual adoption decision making in organizations. Thus, it provides a solid basis for future research. Second, since effective management of new technology depends upon thorough understanding of the diffusion process, much more research is needed. Future research is advised to carefully consider factors discussed above. These factors may not have been important in contexts in which the theory originated but appear to have important effects on information technology diffusion in organizations. Additional retrospective studies could include examination of less structured task environments, technologies with a broader scope, and technologies introduced by IS/IC groups. An accumulation of in-depth case studies would provide additional insight into the diffusion processes now occurring in organizations. And since diffusion occurs over time, longitudinal studies will be critical for understanding how to effectively manage the introduction of emerging information technologies in organizations.*

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* Daniel Robey, Associate Editor. This paper was received on March 12, 1988 and has been with the authors 10½ months for 2 revisions.

Appendix

Level of mass media exposure was measured as follows:

Q. Check off each media source you have used in the last six months.

Business-Related:	*Computer-Specific:*
Wall Street Journal	Computerworld
USA Today	PC Week
Consultant newsletters	Vendor literature
City newspaper	Computer articles in newspaper
Newscasts on television	Computer ads on television
Journal of Accountancy	High Technology
Practical Accountant	Lotus
Managerial Accounting	PC World
Financial World	PC Tech Journal
Fortune	PC Magazine
Forbes	Compute!
Harvard Business Review	MacWorld
Business Week	Family Computing
Newsweek	Personal Computing
Time	Business Software
U.S. News & World Report	Mini-Micro Systems
The Office	Modern Office Technology
Minnesota Business Journal	Computer User

Q. Write in any additional media sources you have used in the last six months.

_____ _____

_____ _____

Q. Number of others (last six months) *not* checked or listed?

_____ Business _____ Computer

Media Exposure = number of sources checked
+ number of sources listed
+ number of sources written-in

Level of external participation was measured as follows:

Q. Check off each of the groups you have belonged to in the past five years.

Business-Related:	*Computer-Specific:*
American Management Association	Assn of Systems Management
Certified Public Accountants	Minn Office Systems Association
Minnesota Public Accountants	EDP Auditors Association
Nat Association of Accountants	TC Accountants User Group
Am Assn of Financial Professionals	Twin Cities PC User Group
Institute of Internal Auditors	Lotus User Group
American Accounting Association	Mini'app'les
Financial Executive Institute	Twin Cities Gold Key Group

Q. Write in any additional professional associations and external groups you have belonged to in the past five years.

_____ _____

_____ _____

Q. Number of others (last five years) *not* checked or listed?

_____ Business _____ Computer

Q. In a typical year, how many meetings held by associations and groups such as those listed above do you attend?

	Business	Computer
External Participation	= number of groups checked	
	+ number of groups listed	
	+ number of groups written-in	
	+ number of meetings attended	

Level of change agent contact was measured as follows:

Q. How often do you talk to other people about computer-related matters? Circle a point on the scales below to indicate how frequently you talk with people from each of the following groups.

a. Technical specialists from the ⟨information center⟩.
b. Other technical specialists from ⟨information systems⟩.
c. Vendors and consultants from outside the company.

Never		About Once/ Month		About Once/ Week		About Once/ Day
0	1	2	3	4	5	6

Change Agent Contact = (item a + item c)/2 [Cronbach Alpha = .70]

Vendor Contact = item b

Category of communication channel usage was measured as follows:

Q. Consider the following sources of information:

(1) Newspaper, TV advertisements
(2) Magazines, vendor literature
(3) Company publications, newsletters
(4) Consultants, vendor personnel
(5) Computer specialists at work
(6) Other colleagues at work
(7) Teachers, friends outside work
(8) Other _____

What source was most influential in your:

(a) Hearing about spreadsheet software for the first time? ___
(c) Forming an impression (positive or negative) about spreadsheet software? ___
(d) Deciding to try using spreadsheet software? ___

Channel Type = 0 (mass media) if source was 1–3; = 1 (interpersonal) if source was 4–7

Channel Source = 0 (external) if source was 1, 2, 4, 5, or 7; = 1 (internal) if source was 3 or 6

Note: channel type and source were computed separately for knowledge stage (item a), persuasion stage (item c), and decision stage (item d).

Adopter Categories were determined as follows:

Theoretic Definition	Sample Definition	Adopter Category
2.5%	3.6% (1979–80)	Pioneer [Innovator]
13.5%	14.6% (1981–82)	Early Adopter
34.0%	33.6% (1983–85.2)	Early Majority
34.0%	32.3% (1985.3–87)	Late Majority
16.0%	15.9% (nonadopters)	Laggards

Adopter Category = 1 (pioneer) if adopted before 1981
= 2 (early adopter) if adopted before 1983

= 3 (early majority) if adopted before 1985.2
= 4 (late majority) if adopted before 1988
= 5 (laggard) if not adopted

Adopter Class = 1 (earlier adopter) if Adopter Category is 1 or 2
= 2 (later adopter) if Adopter Category is 3, 4, or 5

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