A Study of Senior Information Systems Managers' Decision Models in Adopting New Computing Architectures

Akhilesh Bajaj
The Heinz School
Carnegie Mellon University
Room 2105C Hamburg Hall
Pittsburgh, PA 15213

akhilesh@andrew.cmu.edu

Abstract

There has been considerable interest recently in the promise of new computing architectures such as the diskless computing architecture, which runs applications off a network. In previous theoretical work on Information Systems (IS) adoption, the question of whether classical diffusion variables determine the organizational adoption of IS with low knowledge barriers and low user interdependencies is still unresolved. In the practitioner literature, the discussion on new architectures has focused mainly on the costs of ownership of the architectures.

This work proposes a novel methodology for IS adoption studies, using conjoint analysis. Issues such as data collection, data analysis, selecting scales and levels of predictor variables, construct validity, formulating testable hypotheses, and

selecting an appropriate sample size are all discussed. As an example study, factors important to senior IS managers when deciding to adopt a computing architecture for their organization are identified and operationalized. Using conjoint analysis, the relative importance of these factors is measured as well as whether or not the effect of levels of these factors on decision-making is linear.

The findings show that technology factors, which are a subset of classical diffusion variables, are sufficient to explain the adoption of computing architectures, which are a type of IS innovation with low impact on organizational processes and low knowledge barriers for end-users. The software quality associated with an architecture is the most important factor considered by IS managers and its effect is linear. The effect of the cost factor is less important, non-linear, and in some cases, unexpected. The effects of centralization, backward compatibility with the organization, and acceptance by third parties are all linear, but less important than software quality.

Keywords: Senior IS managers, organizational adoption of IS, technology factors, conjoint analysis, software quality.

I. INTRODUCTION

There has been considerable interest recently in the promise of new computing architectures, enabled by languages that write-once run-anywhere, such as Java (Cornell and Horstmann 1996), and cheap, diskless computers (Phillips 1997) that allow the centralization of data and programs on a network server.

For the purpose of this study, a new architecture is defined as *a new computing infrastructure that significantly affects the purchasing and maintenance of hardware and software in an organization*. Depending on one's notion of "significant," this definition allows several computing infrastructures to be considered architectures. For example, we can consider four basic architectures:

- a mainframe architecture, with dumb terminals, where data and programs are centralized on the mainframe and the end-user interface on the terminals is primarily text-based,
- a client server architecture, where data and programs are shared between a client and a server and with primarily a graphical user interface (GUI) on the client,
- a networked architecture (such as an intranet) with diskless network computers, data and programs centralized on the server, and primarily a GUI on the network computers, and
- a fully distributed architecture, where data and programs are scattered fairly uniformly with either a text-based or GUI interface on all machines.

Each of the above has a significantly different cost in terms of purchasing and maintenance of hardware and software.

Previous research on IT **infrastructure** differentiates between the technology components and the human components (Best and May 1997; Broadbent and Weill 1997; Broadbent et al. 1996). The technology components can be differentiated into different levels (Broadbent and Weill 1997). The base level consists of information technology (IT) components like hardware and communication technologies. The next level above is the shared software, such as database management systems. Above that are the actual application programs used to support the data and processes of the specific organization. The technology components are developed/purchased and managed by the human component of IT infrastructure. In the context of this research, our definition of an architecture fits in the base level of the technology component. Our definition of the software associated with an architecture encompasses all of the software associated with it, starting with the operating system and going up to the application programs used by end-users.

Distinctions have been made in the innovation literature on the differences between the *initiation*, *adoption*, and *diffusion* of innovations within and across organizations (Pierce and Delbecq 1977; Rogers 1983). With initiation, pressure to

change can come from either need-pull or technology-push forces (Zmud 1984). Adoption involves the decision to invest resources necessary to accommodate the change effort. This work considers factors that would drive the **adoption** of architectures by an organization, not factors that would influence their diffusion within the organization.

There has been a significant amount of work in the information system, psychology, sociology, and economic literatures that has looked at the adoption of technological innovations in general and IS innovations in particular (for excellent summaries of these literatures, see Fichman 1992; Kwon and Zmud 1987; Rogers 1983; Swanson 1994; Tornatzky and Klein 1982). General results from this past research indicate that several factors can influence the organizational adoption of an IS innovation. Broadly, the influencing factors could describe the organization, its environment, the individuals making the decision to adopt, or the technology itself (the technology factors) (Kwon and Zmud 1987). To the best of our knowledge, the question of whether technology factors, which are a subset of classical diffusion variables, are sufficient to explain the organizational adoption of IS innovations that pose either low knowledge barriers or low new user interdependencies is still unresolved (Fichman 1992). This study answers that question for computer architectures, IS innovations that impose few new user interdependencies and low knowledge barriers for end-users.

The question of what drives the adoption of computing architectures is important for today's IS managers, who are presented with a choice of architectures enabled by new technologies, as well as for vendors of these new architectures. Understanding what drives the decision to adopt their products can allow better positioning of the architectures by emphasizing factors that are considered important by their customers. In the popular press, the debate between proponents and opponents of these architectures has largely focused on the total cost of Ownership (TCO). Thus, several articles have stated that disk-less computers will be cheaper to purchase and maintain (Bray 1994; Francis and Johnston 1997;

Jones 1992). Other articles maintain that the cost will be transferred to maintaining the network (or that "thin clients require a fat network") (Johnston and Francis 1997; Phillips 1997). This debate presupposes that costs are the primary determinant of the decision to adopt a new architecture. In this study, we investigate whether this assumption is reasonable.

The primary purpose of this study is to (1) **identify** the factors that senior IS managers across mid- to large-size organizations would consider when making decisions regarding the adoption of a new architecture for their organization and (2) estimate the **relative importance** and **linearity of effect** of these factors in the IS managers' decision making. Note that the purpose is not to either extol or decry any existing architecture. Thus, the findings of this study are not meant to be predictive with regard to existing architectures; instead, they are meant to offer insights into what drives a senior IS manager's decision to adopt an architecture for his/her organization. The final section of the paper, however, presents a description of how the findings can be utilized in future studies that are more predictive and can be used to compare architectures that are available in the market.

In order to answer these questions, a methodology that is novel in IS research is proposed: **conjoint analysis** (CA). While CA is used widely in psychological and marketing studies for building decision models of subjects, it has been ignored in IS. A major contribution of this work is the proposal of a rigorous research methodology that uses CA, including suitable metrics for a CA study in IS, as well as a list of controls for potential biases, so that CA studies in IS may be replicable and valid.

II. PREVIOUSLY IDENTIFIED FACTORS THAT AFFECT ADOPTION OF IS INNOVATIONS

Previous work differentiates IS infrastructures into technology and human components. The technology component is further decomposed into the base level hardware and communication technologies, application enabling software such as

database management systems, and the actual applications (which are organization specific). Broadbent et al. (1996) look at the capability of IS infrastructure as measured by the services provided by the infrastructure to the organization, the reach of these services (the locations that can be reached by the infrastructure), and the range (the level of functionality that can be shared automatically and seamlessly across each level of reach). Keen (1991) also classifies IS infra-structure along the dimensions of the organizational reach, the range, and the robustness of the infrastructure. In another prescriptive work, Broadbent and Weill (1997) examine how business and IT managers invest in IS infrastructures. They suggest that firms should develop business maxims, which drive IT maxims which drive infrastructure investment. They also suggest that deal making occurs, a method where IS managers simply meet with leaders of business units and supply them with their current needs. In order to have IT enabled flexibility for the future, they suggest that IT investments should be business maxim driven.

This study differs from the prior work on infrastructure along the following dimensions. First, it looks specifically at computing architectures, which map to the base level technologies in the overall IS infrastructure conceptualization. Second, it characterizes computing architectures somewhat differently than the earlier works characterized infrastructure, in that the factors used for classification were gene-rated from interviews with senior IS managers and the factors were **specific** to computing architectures, rather than to a generalized conception of infrastructure.

Several previous works summarize research on the organizational adoption of technology. In a meta-analysis of past research on adoption and diffusion of innovations, Tornatzky and Klein showed that 90% of the studies explained adoption/diffusion in a post hoc fashion, 54% used surveys, 20% used secondary data, and that more than 46% considered only one factor. They identified the 10 factors most frequently posited to influence adoption and diffusion. It is interesting to note that only three factors (*compatibility, relative advantage*, and *complexity*) were found to be significantly correlated with adoption across studies.

In a later study, Kwon and Zmud identified five categories of factors that would influence the adoption and diffusion of IS. The categories are *individual* factors, *organizational structure* factors, *technology* factors, *task* factors, and *environment* factors. In the case of almost all of the factors they listed, the observed effects on adoption/diffusion were either in the expected direction or were uncertain. The only exceptions were the degree of centralization of decision making in the organization (a negative effect was expected but a positive effect observed), the degree of functional differentiation in the organization (a negative effect was expected but a positive effect observed), and the degree of uncertainty in tasks (a positive effect was expected but a negative effect was observed).

Swanson extended innovation adoption theory to IS innovations and classified IS innovations in an organization into three types. Type I innovations affected mainly the organization's IS processes, Type II innovations affected the business and IS processes in the organization, and Type III innovations additionally affected the actual products made by the organization, as well as integration with other businesses. Type I innovations were further divided into Type Ia innovations, which affected only the IS administrative tasks, and Type Ib innovations, which affected primarily the IS technical tasks and, secondarily, the IS administration tasks. It is possible to imagine an organization changing its computer architecture without changing its business processes or its products. However, a change in architecture would usually impact the functions of the IS department (e.g., a shift to a more centralized architecture may cause maintenance staff to be reduced). Hence, based on Swanson's classification, new computer architectures as defined here are Type Ib IS innovations. Chau and Tam (1997) also classify computing architectures as Type Ib innovations. Swanson proposed that organizational characteristics that positively affect adoption of Type Ib innovations are larger organizational size, more slack in resources and more professionally oriented IS staff.

In another summary of empirical research in IS diffusion, Fichman (1992) proposed that IS innovations are of two types. Type I innovations impose a low knowledge burden and/or few new user interdependencies and the primary determinant of adoption is the organization's willingness to adopt. Type II innovations impose a high knowledge burden or high user interdependencies and the primary determinant of adoption is the organization's ability to adopt. Furthermore, Fichman suggested that classical diffusion research (Rogers 1983) has focussed on the willingness to adopt Type I innovations by *individual* adopters and that the *organizational* adoption of Type I innovations is under-researched. Based on Fichman's classification, computer architectures are a Type I IS innovation, with few new end-user interdependencies and low knowledge barriers for end users. Thus, changing from a client server architecture to a network computing architecture will not alter the types of end-user software that are used; if end users use word-processors and spreadsheets with one architecture, they will likely use them with the other as well. The impact on business processes and user interdependencies for performing these processes is also minimal, as described in the previous paragraph.

The intent of this work is not to comprehensively critique recent adoption/diffusion studies, but rather to show how our study fits in with currently understood adoption/diffusion theory. An illustrative survey of recent studies is summarized in Table 1. The purpose of the table is to give a flavor of the kinds of empirical factor-based studies that have been conducted to study IS adoption and diffusion.

**Table 1. Illustrative Summary of More Recent Empirical
Adoption/Diffusion Studies**

Study	Phenomenon Studied	Unit of Study	Methodology Used in Study	Factors Considered in Study as Potentially Influencing the Phenomenon	Results of the Study
Lind et al. (1989)	Adoption of microcomputers.	IS managers.	Structured interviews with IS managers in 21 firms. Regression analysis on data.	Organizational size, structure (organizational linking mechanisms to support adoption), organizational linking mechanisms that support the technical infrastructure.	Size, structure and linking mechanisms that support technical infrastructures all significantly predict microcomputer adoption
Attewell (1992)	Diffusion of computing in firms.	Representative samples of firms.	Secondary data obtained from market research firms. Data were for 1979, 1982 and 1985. Discussion.	Barriers to knowing how to maintain the IS.	The factor was assumed to be influential. The study is a discussion paper.
Grover and Goslar (1993)	Initiation, adoption and diffusion of 15 distinct telecommunication technologies in organizations.	Senior IS managers.	Mailed surveys. Response rate of 21%. Hypothesis testing with regression analysis.	Environmental uncertainty, organizational size, organizational centralization, organizational formalization, organizational specialization and IS maturity.	Environmental uncertainty and decentralization influence greater IS adoption.
Gordon and Gordon (1993)	Adoption of distributed database systems by organizations.	Chief information officers of the top industrial and service companies.	Mailed survey. Response rate of 20%. Regression used for hypothesis testing.	Centralization of management decision making, centralization of the IS function, attitudes of top management towards technology and whether users or top management drive the selection of IS technology.	Organizations with decentralized decision making, decentralized IS functions and where top management is favorable to IS were more likely to adopt distributed databases.

Study	Phenomenon Studied	Unit of Study	Methodology Used in Study	Factors Considered in Study as Potentially Influencing the Phenomenon	Results of the Study
Dos Santos and Pfeffers (1995)	Adoption of auotomated teller machines by retail banks.	Secondary data set.	Multivariate linear regression on the data set was performed.	The dependent variables were change in income and market share. The independent variables were the time of adoption, as well as several control variables.	The impact of adoption on market share and income was higher for innovators than early followers.
Thong and Yap (1995)	IS adoption by small businesses.	CEOs of small businesses.	Mailed survey to random sample. Response rate of 16%. Used t-tests to test hypotheses individually and discriminant analysis to test all variables simultaneously.	CEO innovativeness, CEO attitude to adoption, CEO knowledge, organizational size, competitiveness of environment and information intensity.	Business size, CEO innovativeness, CEO attitiude and CEO knowledge all positively influence the adoption of IS .
Chau and Tam (1997)	Adoption of open systems by organizations.	Senior IS managers.	Indepth interviews followed by questionnaire.	Uncertainty in firm's environ-ment, complexity of current infrastructure, satisfaction with existing systems, formalization of systems development and management, perceived benefits, perceived barriers, perceived importance of complying to open standards	Satisfaction with existing systems and perceived barriers to adoption influence the adoption of open systems

Based on previous research, there appears to be a growing consensus among researchers that IS innovations in an organization are different from other innovations (Fichman 1992; Swanson 1994). IS innovations vary in the knowledge barriers they present, and the interdependencies they create among users. This study investigates which factors occupy the decision models of senior IS managers when considering new architectures, and whether there is a pattern across organizations (with different members, structures, environments, and products) of these factors.

III. CONSTRUCTION OF THE RESEARCH MODEL

Rather than operationalize factors from previous research, the decision was made to use senior IS managers (the subjects of this study) to generate a list of factors that they use in decision making. Support for this approach to factor generation can be found in **grounded theory** (Glaser and Strauss 1967), defined as of categories (or constructs) from systematically obtained data."[1]

A first advantage of this approach is that it generates constructs (factors) that are readily applicable to the empirical phenomenon, preventing "the opportunistic use of theories that have a dubious fit" (Glaser and Strauss 1967). This means that the approach should allow us to come up with a list of relevant factors; if organizational or environmental factors play a major role in the decision to adopt architectures, they should reveal themselves. Second, this approach generates operationalizations of factors that are understandable to the subjects. For example, even if we selected a subset of factors from past work that we posit will influence the adoption of architectures, senior IS managers (the subjects) may not perceive them in the same way as academics. For example, the *relative advantage* factor in previous innovation theory would need to be explicitly operationalized, *in the context of architectures*, before it can be used.

---

[1]Note that a pure grounded theory approach is not being followed in that we are looking at previous literature as well when identifying the list of factors.

Semi-structured interviews were used to collect data that would identify and operationalize factors important in the decision models of senior IS managers when deciding to adopt a new architecture. A database listing large corporations in Pittsburgh, Pennsylvania, a large metropolis in the eastern part of the United States, was used to identify subjects. A large corporation in the database is defined as one having "greater than 250 employees." The database population consists of 232 firms. The following process was used to identify the factors: corporations were randomly selected from the database, their senior IS managers were interviewed, and a list of factors relevant to the senior IS manager was determined. A decision was made to continue interviewing senior IS managers from different organizations in the database until there was consistency in the factors that identified. This method of sampling is valid when the goal is to identify broad constructs rather than to perform statistical tests. Glaser and Strauss term this method "*theoretical sampling until saturation*" and contrast it with statistical sampling. Ten firms were contacted at random (from the population of 232) and senior IS managers in eight of these firms agreed to be interviewed.

Each interview was conducted as follows. The IS person who fit the definition of "senior IS manager" was identified and approached for an approximately hour long semi-structured interview. The interviews were conducted in person (three interviews), as well as on the phone (five interviews). All interviews were conducted by the same researcher. At the start of each interview, the IS manager was briefed on what architecture meant for this study. Examples of architectures, described in section I, were given to the manager. The manager was then asked in an open-ended style to list what would make them adopt an architecture, within their particular organization. Once they had listed an initial set of factors, the interviewer went over the list with them to ensure there was no ambiguity or misunderstanding. The manager was also asked to give an approximate ranking of the factors he/she had listed. Care was taken to not point out any new factors to managers, but to let them list factors. In all cases, the managers added factors to the initial list as the

interview progressed. The end product of each interview was a half page to one page summary of factors, in rank order, that were important to the IS manager.

After five interviews, an intermediate check was performed and the data collected was analyzed. There was consistency in the factors that were pointed out. A further three managers (giving a total of eight) were interviewed in a similar fashion. Table 2 summarizes the information collected from each manager. Each factor is described using the terminology of the IS manager interviewed. The factors are listed in descending order of specified importance for each IS manager. As columns two, three, and four in Table 2 indicate, the IS managers were from (randomly selected) organizations with varying SIC codes and sizes, were all senior, and represented a reasonable spectrum of experience. For convenience, the first factor identified by the second IS manager in the table is referred to as factor 2.1, etc.

The next step was the all-important one of inducing a final list of factors from these empirically determined descriptions. Care was taken to keep two things in mind. First, the factors coming from the descriptions had to be reasonably independent of each other, i.e., there should not be significant semantic overlap in the mind of an IS manager between the factors. This follows from the well-known need to use orthogonal factors in empirical models when explaining or predicting a phenomenon.[2] Second, the factors had to represent a large portion of the decision models of the IS managers interviewed. The exercise would have been fruitless if there had been no significant intersection between the factors stipulated by different IS managers; in that case, the phenomenon of architecture adoption would be inherently unstable. Thus, the factors had to be a subset of previous theory and reasonably canonical (orthogonal and reasonably complete) in order for the approach to work.

---

[2]The question asked to test orthogonalty was: Is it reasonable to assume that, for architectures, the value of one factor does not influence the value of another factor?

Table 2. List of Factors Verbally Identified by Senior IS Managers During Interviews

No.	SIC Codes	Number of Machines Managed	Years of Experience	List of Factors Considered by the Senior Is Manager When Adopting an Architecture
1	10	35+	30	1. Security of data and programs 2. Costs of purchasing and maintaining the software, availability of personnel to maintain hardware and software 3. Stranglehold of software vendors on market 4. User's perceptions of quality of software in workplace as compared to outside workplace
2	58, 70, 72	100+	10	1. Ease of maintaining hardware and software and service personnel availability 2. Centralization of information 3. Security of data and programs 4. Quality of software and user satisfaction with it
3	3547	300+	14	1. Existing sunk costs in hardware, training costs of IS people and users in new architecture 2. Centralization of hardware and software for security 3. The cost of maintenance of the hardware and software 4. End user satisfaction with the system
4	Non-profit community college	300+	4	1. Maintenance costs for the new architecture 2. Quality of software and ease of use of software, reliability of software and hardware 3. Control of the information by the senior IS manager
5	Non-profit human services	40+	8	1. Overall popularity of the architecture among Fortune 500 companies, media, etc. 2. Autonomy of users (sense of virtual ownership of the data and programs) should be pre-served 3. Existing large vendors should support the architecture 4. Political support in the organization from CEO and CFO 5. Security and control over the data and programs
6	34	1000+	12	1. Acceptance by the vendors and media 2 Quality and reliability of software 3. Ability of new software to read old data 4. Costs of purchasing and maintaining the hardware and software

No.	SIC Codes	Number of Machines Managed	Years of Experience	List of Factors Considered by the Senior Is Manager When Adopting an Architecture
7	36	NA*	NA	1. Availability of software by different vendors 2. Backward compatibility of software with old data 3. Costs of maintenance
8	89	200+	15	1. Productivity of users with new architecture 2. Vulnerability of failure of hardware or software 3. Popularity of architecture with peer organizations

* NA= Not Available

Table 3. Final List of Factors Derived Empirically from Interviews

Factor	Broad Definition
Software quality	The quality of software associated with the architecture. This can include response time to end-users, quality of user interface and features provided by the software.
Centralization vs. distributed nature	A centralized architecture means that software resides in a centralized location, and most of the hardware investment is also centralized.
Costs	The costs of an architecture include the costs of acquisition of hardware, software, the costs of maintenance of hardware, of controlling different versions of the software and the costs of personnel trained in maintaining the hardware and software.
Acceptance of the architecture	This factor represents the degree to which a particular architecture has been accepted by IS magazines, the media, model organizations and software and hardware vendors.
Backward compatibility of the architecture	This factor models the degree to which an architecture will cause changes in the organization. Changes include: converting old data to be read by the new architecture, retraining users to use and and IS personnel to maintain the software and hardware.

The factors induced are shown in Table 3. As mentioned above, *both the results of these interviews as well as previous theory were used to arrive at the final list of factors*. The definitions are derived from the terminology of the IS managers interviewed. The mapping between the factors identified in the interviews and these

final five factors is shown in Figure 1. The numbering scheme in Figure 1 is *interviewee_number.factor_identified*. Thus, factor 1.4 is the fourth factor identified by the first subject. Based on Figure 1, it is safe to assume that these factors, as defined, are reasonably independent of each other, represent a large percentage of an IS manager's decision model when making adoption decisions regarding adoption of an architecture, and are readily understandable by senior IS managers.
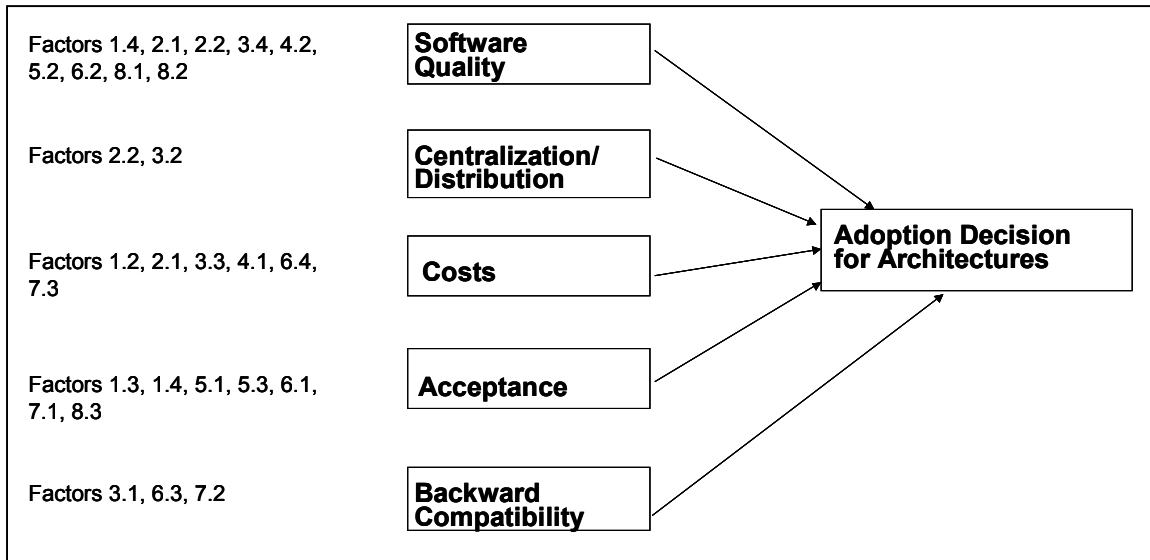

**Figure 1. Mapping Between the Factors Identified in the
Interviews and the Final Five**

It is interesting to see how these five empirically obtained factors map to classical diffusion variables.

It is widely accepted in the adoption of innovations literature that complexity and ease of use represent the same concept (Kwon and Zmud 1987; Moore and Benbasat 1991; Tornatzky and Klein 1982). As defined here in Table 3, poor software quality of a computing architecture implies that software associated with the architecture has at least one of the following problems: a poor response time, a poor user interface, incomplete or excessive features. All of these contribute to the architecture being harder to use. Thus, as defined here, **software quality**

encompasses most of the aspects of *complexity* or *ease of use*. Keen defines an IS in terms of reach, range, and robustness. The concept of software quality used here is broader than robustness, and incorporates usability and response time.

To **centralize** IS or not is an issue that has been much debated in the IS literature (e.g., Allen and Boynton 1991; King 1983; Wyner and Malone 1996). As defined here, a centralized architecture is one where the data and programs are centralized on a few machines, while a decentralized architecture is one where the data and programs are scattered across machines. The benefits of centralization are widely touted as increased control, uniformity of operations, and economies of scale. The benefits of decentralization include bottom-up productivity improvement, greater autonomy to end users, and the ability to customize IS for frontline organizational functions. While only two IS managers included centralization as a factor in the interviews, it was included in the study because of its importance in previous literature. Also, given the recent interest in the new architecture of network computers running off an intranet server (more centralized) vs. a multiple personal computer architecture (more distributed), consideration was given to whether or not centralization would be an important factor in the adoption of future architectures.

The **costs** factor is explicitly mentioned by Tornatzky and Klein and has been used in several past innovation studies that they list. Note that in the definition used in this paper, *costs* only includes the explicit costs incurred by adopting the new architecture. This includes the costs of hardware and software acquisition, as well as training and personnel costs for maintenance. Intangible or implicit costs such as "loss due to user productivity" are not included in cost.

The **acceptance** of the architecture encompasses all aspects of the *social approval* or *image* construct (Moore and Benbasat 1991). If an architecture has greater acceptance with other organizations and the media, then adopting it is likely to lead to greater social approval within and outside the organization. The empirical derivation of *acceptance* as a separate factor supports Moore and Benbasat's contention that *image* is a stand-alone factor. Intuitively, architectures appear to be

the kind of technology where network externalities (Katz and Shapiro 1986; Markus 1987) may play a role in the adoption decisions of organizations: the more accepted the architecture the higher the subsequent adoptions.

The **backward compatibility** factor clearly maps to the *compatibility* factor in Kwon and Zmud, Moore and Benbasat, and Tornatzky and Klein.

It is interesting to see why some factors in the literature do not show up on the list. The *trialability/divisibility* factors (Tornatzky and Klein 1982) simply did not occur to any of the IS managers interviewed, and hence it was concluded managers would not consider it when decision making. The interviews specifically asked the managers to think of architecture adoption, so it can be argued that the *differences* in trialability/divisibility of existing architectures (i.e., how easy is it to try an architecture with minimal commitment) are not important enough to be a concern to IS managers, although clearly the same cannot be concluded for other innovations. *Communicability* (how easy it is to communicate the benefits of an innovation to other potential adopters) is also not present. It is useful when studying the *diffusion* of an innovation, but not applicable when the phenomenon is an adoption decision by one individual or organization. The only way it could be applied here (an *adoption* study) is if senior IS managers of different organizations are assumed to significantly influence each other's adoption decisions for their organizations, an assumption this study felt safe in discarding.

The *security* of an architecture appears to be important (see factors 1.1, 2.3, 5.5 in Table 2). Intuitively, security appears to be a *threshold* factor. This means that security needs to be at a minimum acceptable level for an architecture to be even considered for a large organization. So, it makes little sense to even consider architectures with low security: an acceptable level of security is required for all architectures. Most current architectures are not very different from a security standpoint at the hardware or operating system levels; the differentiation seems to be at higher levels and one differentiator seems to be whether the data and programs are centralized (managed by IS personnel) or distributed (managed by

end-users). For these reasons, security was not considered as a standalone factor. Rather centralization/distribution was listed as a standalone factor, incorporating the aspect of security along which potential architectures are likely to differ.

The only organizational factor mentioned in Table 2 is 5.4. It should be noted that factors related to *individuals* in the organization, the *organization structure*, the *task*, and the *environment* (organizational factors listed by Kwon and Zmud) do not show up on the list, implying they are not explicitly considered by IS managers when deciding to adopt architectures.

Finally, *relative advantage* does not show up explicitly on the list. *Relative advantage* has been criticized as being too general a factor (e.g., Moore and Benbasat 1991; Tornatzky and Klein 1982). As Tornatzky and Klein state, "typically it is the garbage pail characteristic in innovation characteristic studies, into which any of a number of innovation characteristics are dumped." The feeling expressed int his study is that relative advantage is the *effect* of all the factors, as opposed to being a different factor in its own right. Thus, better *software quality*, *lower costs*, better *acceptance*, more *backward compatibility* and either *centralization* or *decentralization* (depending on what is preferred) would all conceivably lead to a greater *relative advantage*, which would lead to adoption. As Table 2 indicates, no IS manager thought about their adoption decision process in terms of evaluating the relative advantage of architectures.

Table 4 summarizes the mapping of the empirically derived factors to factors used in two comprehensive earlier studies by Kwon and Zmud and by Tornatzky and Klein.

Table 4. Mapping Between Factors Used in Previous Studies and the Final Five Empirical Factors

Name of Factor in Previous Literature	Description of Factor in Previous Literature	Correlation of Earlier Factor with Adoption/ Diffusion of Innovation	Factor Used in Our Study that Maps to Factor in Column 1
Tornatzky and Klein (1982)			
Compatibility	Degree to which the innovation is perceived as being consistent with existing values, past experiences and needs of the receivers	Positively correlated	Backward compatibility
Relative advantage	Degree to which the innovation is being perceived as being better than the idea it replaces	Positively correlated	None
Complexity	Degree to which the innovation is perceived as being relatively difficult to understand and use	Negatively correlated	Software quality
Cost	Not defined	No conclusive data	Costs
Communicability	Degree to which the aspects of the innovation may be conveyed to others	No conclusive data	None
Divisibility	Extent to which the innovation can be tried on a small scale prior to adoption	No conclusive data	None
Profitability	The level of profit to be gained from adopting the innovation	No conclusive data	None
Social approval	Status gained in one's reference group from the innovation	No conclusive data	Acceptance
Trialability	Degree to which the innovation may be experimented with on a limited basis	No conclusive data	None
Observability	Degree to which the results of the innovation may be visible to others	No conclusive data	None
Kwon and Zmud (1987)			
Compatibility	Innovation's organizational "fit," as well as its impact on individual's attitude regarding change, convenience of change and power shifts.	Positive	Backward compatibility
Relative advantage	Degree to which current innovation is perceived as providing greater organizational benefit than other innovations and the status quo	Positive	None
Complexity	Degree of difficulty users experience in understanding and using an innovation	Uncertain	Software quality

IV. THE RESEARCH STUDY

WHY SENIOR IS MANAGERS?

All subjects in both phases of this study (identification of factors described in section III, and the estimation of relative importance and linearity of factors) were senior IS managers, who were well informed about new external developments in IS and were also decision makers in terms of making significant new investments in IS within the organization.

Using Swanson's classification, architectures are a Type Ib IS innovation, which impact the IT technology and administration, but do not significantly impact the organizational processes or products. Thus, the decision to invest in these innovations is more likely in the hands of senior IS managers than business managers. In a detailed study, Pervan (1998, p. 101) shows "substantial overall agreement between CIOs and CEOs on key IS issues in large organizations." Support for using senior IS managers is also provided in organizational literature on technological adoption that analyzes the role played by *champions* in adoption (e.g., Ettlie et al. 1984; Howell and Higgins 1990). The definition of a senior IS manager used in this paper identifies those who are likely to be champions of a new architecture in an organization, or at the very least whose support is required by potential champions of a new architecture. Finally, much of the past empirical work on adoption has used senior IS managers as subjects (e.g., Gordon and Gordon 1993; Lind et al. 1989; Zmud et al. 1987). In their meta-study of past innovation adoption/diffusion research, Tornatzky and Klein found that about 14 past studies had used key decision makers as their subjects. Based on these past findings, the decision was made that senior IS managers are the best subjects for studying the adoption of architectures within their organizations.

USING CONJOINT ANALYSIS STUDY TO ESTIMATE THE RELATIVE IMPORTANCE OF EACH FACTOR

This study used conjoint analysis (CA), a well known method in mathematical psychology (Luce and Tukey 1964) and marketing (Green and Rao 1971) but, as far as could be determined, novel to IS research. Since it is novel, a description of CA is given in Appendix D and a methodology that can be used to implement CA studies in IS is presented. Next, the CA study conducted to estimate the relative importance of each factor identified earlier is described.

A CA STUDY ON IS ARCHITECTURES

The steps to be used in a CA study are summarized in Figure 2.

---

1. Identify the product or concept of interest as a product class. Identify attributes important in the decision space when making evaluation decisions.

2. Select appropriate levels for each factor (a.k.a. attribute or predictor variable).

3. Operationalize each factor in a manner suitable for the data collection technique being used.

4. Create study packet and pilot test for clarity of measures, time taken for one study, any other implementation problem or possible biases.

5. Select random samples of subjects from population.

6. Administer the study to the subjects.

7. Analyze data, test hypotheses, and present results.

Figure 2. List of Steps that Constitute a CA Study

The first step, the creation of the product class and the identification of factors, was described in section III. The second step was to specify levels for each

factor. In all cases, the levels chosen were high, medium, and low, except for the *centralization/decentralization* factor, which was either centralized or distributed. Note that the usage of semantic scales is well accepted in the adoption/diffusion literature, since virtually every study examined uses semantic Likert scales. An additive model was studied to study the effects of the factors:

architecture adoption likelihood = Software Quality effect + Centralization/Distribution effect + Costs effect + Acceptance effect +Backward Compatibility effect **(1)**

The well known SPSS statistical package was used to generate 16 hypothetical architectures,[3] each characterized by one value for each of the five factors. In addition, to test the internal validity of the responses of each subject, four holdout architectures were also generated. Thus each subject would be given the same 20 architectures. The 20 hypothetical architectures used for the study are shown in Appendix A. An examination of the architectures indicates that none of the hypothetical architectures that are used are "unrealistic" in the real world.

The third step was to operationalize the factors. The decision was made to collect data face-to-face, with each subject performing the study in the presence of a researcher. A richer operationalization of factors was permissible, since each subject was administered the study by the same researcher in person, and hence reliability and validity controls were implemented on site. For each factor, the definition (as in Table 3) and a reason why the factor was important were given. The reasons were kept moderate, so as not to bias the subjects in favor of any factor. In the case of *software quality*, *backward compatibility*, and *acceptance*, the reason was formulated to make the factor's effect moderately positive (i.e., higher was better than medium, which was better than lower, based on the reason). In the case

---

[3]Several tools (see an extensive listing in Hair 1992) exist for constructing orthogonal fractional-factorial designs (i.e., a subset of products in the product class that eliminates multi-collinearity), as well as for allowing data collection and analysis for CA studies.

of *costs*, the example served to make the effect negative. The *centralization/ decentralization* factor was treated differently. The pros and cons of centralization versus distribution are well documented in the IS literature (e.g., Allen and Boynton 1991; King 1983). Hence, one reason was given why centralization may be beneficial and another reason why distribution may be beneficial. The idea behind all the reasons was to simply highlight to the subject the pros of each factor and to achieve relatively uniform awareness among the subjects about what each factor meant. The examples were chosen so that, prima facie, there was no reason to believe that one factor would be preferred over the other. Note that the study involves **trading off** between factors, and so any importance given by a subject to one factor has to come at the expense of another factor.

The fourth step was the construction and pilot testing of a study packet, which was to be used in the actual study. The 20 architectures were printed on separate cards of identical length, breadth, and thickness. The study was pilot tested with three doctoral students with high, moderate, and low IS experiences respectively. Based on the feedback, the following changes were made in the packet. Since the order of appearance of a factor on a card was important, five different study packets were created. Across the study packets, each factor showed up first in all the cards of one packet, second in all the cards of another packet, etc. Of course, the *same* 20 architectures were presented in each packet; only the order of factors describing each architecture on a card was changed across the five packets. The cards would be shuffled before being handed out to each subject, and the cards were titled from A to T, with the explicit mention to the subjects that the letters were chosen at random. Finally, the presentation (font size, etc.) on all cards was identical. The researchers also ensured that the operationalization of each factor was easily understood by all three pilot study subjects. There was a tendency among the pilot study subjects to attribute too many intangibles to the *costs* factor. All three subjects reacted very similarly to the study, which increased confidence

somewhat in the reliability of the final study. One final study packet (out of five) is shown in Appendix B.

A description of how **reliability** and **construct validity** were ensured with each subject in the actual CA study is now given. Each study was conducted with one subject, in the presence of a researcher. The instructions in the packet asked the subject to read the descriptions of the factors. The next step in the study was for the researcher to answer any questions the subject may have regarding the descriptions of the factors and to ensure that the subject had an understanding of how each factor was different from the other. Particular care was taken to distinguish between *cost* and the other factors. It was specified that only explicit, tangible costs needed to be considered, and not intangible costs like "loss of user productivity." This dialogue with the subjects was necessary to ensure that all subjects had a similar understanding of the five factors. At this stage, they were also asked if, in their opinions, any important factors had been omitted. This was an added, informal check on whether the factors were complete.[4] Once the researcher was satisfied that the subject had a good understanding of the different factors, the subject was asked to rank order the cards in descending order of preference. It was specified at this point that the subject should rank the *cards in the context of what would be adopted in his/her organization*, as opposed to a general ideal norm that the subject may have of architectures. No time limit was to be set for the ranking and it typically was expected to take between 20 and 30 minutes to perform the ranking. Once the cards were rank ordered, the subject was to give a score of 100 to the highest card and 1 to the lowest card. The remaining cards were each to be given any score, as long as a strict order was maintained. These scores would be the (metric) dependent variable in the study and would represent likelihood of adoption of the architecture on that particular card.

---

[4]All of the subjects in the study described next indicated that the five factors adequately covered what they would consider when decision making.

Once the packets were ready, the firms for the study were selected. From the same database of 232 large firms used in the earlier interviews, a random sample of 30 firms was generated. The senior IS manager of each firm was contacted and a personal meeting was set up for the study. Special care was taken to ensure that each subject was indeed the chief decision maker for IS purchases within that firm (or division of a larger firm). The subjects were contacted over a period of two months. In our judgment, no external events of sufficient magnitude[5] occurred so as to bias subjects in the latter or earlier periods of the study. Table 5 contains the details of response rate of our sample.

Table 5. Details of Response Rate of Sample

Agreed to study	Organization does not exist any longer	Organization unit not responsible for decision making of it procurement	Contacted, but did not return repeated calls	Declined to participate	Total organizations In sample
23	1	2	3	1	30

The demographics of the 23 IS managers who agreed to participate are shown in Table 5.

---

[5]A hypothetical example of such an event is a particular architecture that is highly centralized is accepted as a worldwide standard, biasing all subjects in favor of centralized architectures.

Table 6. Demographics of Subjects Who Participated in the Study

Subject No.	Gender	Years of Experience	Approximate Number of Machines for which Manager is Responsible	Environment They are Most Comfortable Managing*	SIC Code of Organization or Services Provided by Organization
1	M	18	400+	Client/Server	SIC 99
2	M	7	100+	Mainframes	Design and build coil processing systems
3	M	20	155	Client/Server	SIC 3612
4	F	20	1,000+	Client/Server	SIC 89, 28
5	M	32	135+	Mainframes	SIC 3316, 3362, 3533
6	M	6	78	Fully Distributed	Supply hi-tech personnel
7	F	13	350+	Mainframes	Distribute heavy construction equipment
8	M	8	500+	Client/Server	Hospital Systems
9	M	11	1,200+	Fully distributed	SIC 3465, 3711, 3713
10	M	15	20,000+	Mainframes, Client/Server, Fully Distributed	SIC 3334, 3353, 3354
11	M	15	42	Client/Server	SIC 99
12	M	12	1,000+	Client/Server	SIC 6711, 6722
13	M	20	30,000+	Fully distributed	SIC 3355, 3857
14	F	20	40,000+	Client/Server	SIC 2819, 1051, 3399
15	M	17	200+	Mainframes	SIC 3544
16	M	8	950	Mainframes	SIC 4011
17	M	27	250	Mainframes	SIC 3317, 3531
18	M	3	50	Client/Server	SIC 3316
19	M	6	475	Client/Server	SIC 99
20	M	20	28,000+	Mainframes, Client/Server, Fully Distributed	Banking
21	M	9	80+	Client/Server	SIC 70.72
22	M	25	20,000+	Mainframes, Client/Server	SIC 1011, 1211,1311, 3312, 4923
23	M	13	150	Mainframes, Client/Server	SIC 2829

*This information is shown to demonstrate that the sample set was indeed varied. The 20 architectures in the study were all hypothetical and this was explained to the IS managers.

DATA ANALYSIS

In this case, the dependent and independent constructs were metric. Hence, dummy variable regression analysis (using the well known Excel package) was used to estimate a part-worth model for each subject (each IS manager). **Internal validity** in a CA study translates to whether or not each subject's decision model represents a consistent logic or not. Internal validity of each individual subject's model was tested based on the hold out sample of four cards for each subject. The Wilcoxon rank test[6] (Wonnacott and Wonnacott 1984) was used for this. The test ranks observations from different populations (in this case, the two populations are predicted values and actual values) and then answers the question: are the two populations significantly different from each other? Note that this kind of internal validity check is impossible to do with mailed surveys, where each subject is only one data point for an aggregate model and, hence, no individual level model can be formed. In all 23 cases, the IS managers had valid internal decision models.

Based on the dummy variable coding scheme for the 16 architectures (as represented by the factors) used, the part worth estimates are on a common scale. Hence, the overall relative importance of each independent factor for a subject can be easily computed by looking at the range of part worths across the levels of that factor.

RESULTS

The expected part worth of each factor is 20% (since there are five factors). Two metrics are used to present the results. The first metric is *the mean relative part worths* of each of the five factors and the *confidence intervals* of these means. This metric is equivalent to testing a null hypothesis that all five factors have an equal effect in the minds of the senior IS managers. Since the mean part worth can

---

[6] An analysis of variance could not be used, since the populations are small (four observations each). A larger population would have meant a larger holdout sample, which could have cognitively overloaded the subjects, thus leading to serious biases in their responses.

be biased by extreme values in the sample, a second metric, which gives *the percentage of subjects in the sample* that indicated a higher than the expected 20% relative part worth for each of the five factors is used. Table 7 shows the relative part worths, standard deviation, and confidence intervals for each factor. It also depicts the percentage of subjects who thought it was significant (i.e., had a part worth over the expected 20%), the direction of influence in these cases, and the linearity of effect across the different levels of each factor. The data and figures used for the results are in Appendix C.

Table 7. Summary of Results of the Study

Factor	Means	Std Dev.	95% Confidence Intervals[a]	Importance[b]	Direction of Slope of line[c]	Linearity of Effect[d]
Software quality	40.2	16.9	32.8 – 47.6	86%	All 20 positive	All linear
Centralization/ distribution	16.4	13.3	10.58 – 22.22	39%	Four subjects positive, five subjects negative.	NA (only two levels)
Acceptance	15.9	14.8	9.41 – 22.38	17%	All four positive.	All linear
Costs	14.4	10.2	9.93 – 18.86	26%	Three out of six subjects positive from low to medium costs.	Non linear
Backward compatibility	12.9	5.1	10.66 – 15.13	13%	All three positive.	All linear

[a] Degrees of freedom = 18.
[b] This is the percentage of subjects for whom the relative part worth was greater than 20% for this factor.
[c] This is the direction of the slope of the line only for those subjects for whom the factor had a relative part worth greater than 20%.
[d] Only for those subjects for whom the factor's relative part worth greater than 20%.

V. DISCUSSION OF FINDINGS

For the purposes of this discussion, it is assumed that if a factor has a relative part worth greater than the expected value of 20% it plays an important or significant role in the subject's decision model.

The positive slopes for *software quality* imply that it positively influences the dependent variable. Also, the effect of software quality is reasonably linear, across different levels, in most cases. As Table 7 indicates, the mean relative part worth of software quality is much higher than the other factors. Its confidence interval range is higher than the confidence interval range of the other four factors, which is statistically significant. On the second metric, 86% of the subjects gave greater than expected importance to software quality. This implies that, when selecting an architecture, software quality plays the most important role in influencing the adoption decision.

The slopes for *centralization/distribution* show a **mixture** of positive and negative slopes. A positive slope implies that a distributed architecture is preferred over a centralized architecture, while a negative slope implies that a centralized architecture is preferred. This divided view about the merits and demerits of centralization vs. distribution is not new and several studies have been devoted to it. The findings presented here support the validity of this debate in the academic literature (Allen and Boynton 1991; King 1983; Wyner and Malone 1996). Since this factor has only two levels, it is not possible to make comments about the linearity of its effects. As Table 7 indicates, its confidence interval is fairly large, indicating its effects vary widely. A total of 39% of the subjects gave greater than expected importance to *centralization/distribution* in their decision making.

A negative slope for *costs* is expected, since that implies that lower costs are preferred to higher costs. However, in half the cases that held costs significant, the slope between low and medium costs is **unexpectedly** positive, implying that the IS managers would prefer architectures with medium costs over low costs. Also, the cost factor appears to be non-linear in the effect of different levels of cost (non-

linear means that the slope of the part worth values of different levels of cost is non-linear). This unexpected positive slope between low and medium costs indicates a mixed attitude toward *costs* in the minds of some subjects. Note that this is in contrast to a mixed attitude toward *centralization/decentralization* across subjects. Two of the three subjects who preferred medium costs to low costs were interviewed and the explanation they offered was that, in their minds, *low costs imply low quality* and it is very difficult to unlink costs and quality. This will obviously also lead to mixed effects of costs on the dependent variable. As Table 7 indicates, the *costs* factor had a fairly large confidence interval and 26% of the subjects gave it greater than expected importance when selecting architectures.

The expected positive slope of *acceptance* implies that higher acceptance is better. *Acceptance* also appears to be linear in its effect. Also, as Table 7 indicates, *acceptance* has a large confidence interval, indicating that its effect on IS manager's decision models varies widely. Only 17% of the subjects gave greater than expected (20%) importance to *acceptance* when selecting architectures.

The expected positive slopes for *backward compatibility* indicate more compatibility is better in the minds of most managers. It is also reasonably linear. In two additional cases (subjects 13 and 14), compatibility's part worth is nearly 20%. For subject 13, the slope between low and medium compatibility is unexpectedly negative, indicating that the subject's order of preference is high, low, and medium compatibilities. In a short follow-up interview, the subject indicated that he believed that, in general, change was good for his organization. As Table 7 indicates, *backward compatibility* has a fairly tight confidence interval, indicating that its effect on manager's decision models is fairly consistent. Only 13% of the subjects gave greater than expected (20%) importance to *backward compatibility*.

The study's findings are summarized in Table 8.

Table 8. Summary of Findings from the Study

The most important technology factor driving the adoption of an architecture is the *software quality* associated with the architecture.
Centralization/distribution, costs, acceptance, and *backward compatibility* are also technology factors that will influence the adoption of an architecture, but are relatively less important than software quality.
The effects of levels of *software quality, acceptance*, and *backward compatibility* are linear for an individual IS manager.
The effect of levels of *costs* is non-linear for an individual IS manager.
The directional effects of *software quality, acceptance*, and *backward compatibility* are positive both for individual managers and across a population.
The directional effect of *centralization/distribution* is positive for some IS managers and negative for others. Its effects vary across the population.
The directional effect of explicit *costs* on individual IS managers and across the population is uncertain.

The study also tested whether there was any correlation between the architecture that a manager was most comfortable with, and the relative part worths of the factors. For example, is it the case that managers who are most comfortable with mainframe architectures tend to value centralization as being more important? A correlation matrix revealed low correlation (less than 0.3 in all cases) between the architectures that IS managers were comfortable with managing (an item in the questionnaire in Appendix B) and the relative part worths of the factors.

The most important findings from the study are now related to previously identified factors.[7] The importance, positive slope and linearity of the *software quality* factor imply that the *complexity* or *ease of use* of the software associated

---

[7]See section III for a qualitative mapping of the factors in this study to those in previous theory.

with an architecture[8] is the most important factor considered by IS managers. The other four factors are much less important at the aggregate level.

In the case of *acceptance* and *backward compatibility*, the effect is as expected, but the importance (as signified by their relative part worths) is low. This implies that the *social approval*, *image,* and *compatibility* factors in previous work all affect architecture adoption positively, but less than *software quality*. Also, their effects on decision making are linear at all levels of the factors. In the case of *centralization*, the effect is consistent for each subject, but varied **across** subjects (i.e., some prefer centralization of data and programs and some prefer distribution). This supports the validity of the debate in literature on the merits and demerits of centralization. In the case of tangible *costs*, the effect is mixed even **within** each subject, as indicated by the non-linearity and, in many cases, unexpected slopes of the cost factor.

LIMITATIONS OF THE STUDY

First, the methodology followed here precludes the inclusion of personal factors (since factors are generated from interviews with the subjects themselves) as potentially influencing the adoption decision. Thus, it is impossible to have a subject listing his or her own personal factors as a factor they would consider when making an adoption decision, since this would involve having them imagine themselves as different from what they are! Post hoc studies of adoption, which are more common in the literature, are suitable for studying the effects of personal factors in the adoption of IS.

---

[8]The software associated with any architecture can be split into several levels, starting from the operating system at the bottom, moving up to application systems such as database management systems, moving up to end-user applications such as database form applications. Each level's quality depends on the levels below it. In this study, software is defined as all the software that all members of the organization would interact with. Thus, IS staff may interact with the operating system and the next higher level, while end-users may react only with the highest levels. Ultimately, the goal of an organizational IS is, of course, to deliver end-user software, and in the definition of software quality (see Table 3), this focus is stressed.

Second, like all data collection involving close interaction between the researcher and the subjects, this study's validity is heavily dependent on the researcher. In this study, great care was taken to document the steps utilized to ensure validity and reliability of the factors. Because of this documentation, a replication of this work by other researchers is possible, but the burden for ensuring replication is greater than for a mailed survey, where the instruments are usually easily replicable and interaction between the researcher and subjects is minimal. Reliability and validity of the factors are more qualitatively determined in a face-to-face study than in a mailed survey (where quantitative measures of construct validity and reliability exist).

A third limitation of this approach is the operationalization of factors. In this study, factors were operationalized based on interviews, previous factors in theory, as well as based on informal discussions with other researchers. However, the determination of the orthogonality and completeness of the operationalization is qualitative (unlike using, say, factor analysis).

VI. CONCLUSION

The findings in this study contribute to both IS theory and practice. The contributions to **IS theory** are as follows. First, a new methodology is proposed that describes how to conduct IS studies using CA and how to control for different biases that may arise. It is hoped that this is the first of several future CA studies in IS. Examples of product classes that can be created in future CA studies include classes of software tools, such as CASE (Computer Aided Software Engineering) tools and ERP (Enterprise Resource Planning) tools, and hardware/operating system combinations. For any of these product classes, a CA study, as described in detail here, is likely to yield new and useful insights into decision models of consumers of these technologies.

Second, a first step is taken toward showing that, for Type I innovations as defined by Fichman (1992) with low knowledge barriers and user interdepen-

dencies, classical diffusion variables are sufficient to explain organizational adoption. Specifically considered are architectures, which are a Type I innovation and generate technical factors (a subset of classical diffusion variables) that play a dominant role in the decision models of senior IS managers. Another finding is that there is a definite *pattern* across a random sample of large organizations in the magnitude, direction and linearity of effects of these factors; the pattern is summarized in the propositions of Table 8. The intuitive support for this finding is that computing architectures (like other Type I IS innovations) cause sufficiently little change in organizational processes and products so that organizations consider mainly technical factors when deciding to adopt them. This finding gives important insight into what drives the adoption of computing architectures in an organization and thus contributes to the existing literature on computing infrastructures.

Third, the relative importance of each of these technical factors is measured and software quality, as defined here in Table 3, is found to dominate the adoption decision. This indicates that complexity (or ease of use) is the primary driver in the organizational decision to adopt Type I IS innovations. This finding lends support to the meta-analysis conducted by Tornatzky and Klein, who found that complexity (or ease of use) is one of only three factors that affects adoption of innovations across research studies, the findings of Attewell (1992) regarding the lowering of knowledge barriers as a factor affecting organizational adoption, and work by Chau and Tam, who found that the organization's ability to adopt is the important factor in determining the adoption of open systems. The finding here goes against the findings of Ditsa and MacGregor (1997), who found that IS managers in small to medium organizations did not consider the usability of the software from the point of view of end users. The discrepancy in their findings could be due to the fact they considered small to medium sized firms in and around Sydney, Australia, while this study considered large size firms in Pittsburgh, Pennsylvania. The findings in this study indicate that IS managers of these firms are aware that the biggest cause of software failure is poor usability (Markus and Keill 1994).

Fourth, the linearity of effect of the levels of the factors identified is established. The results indicate that the use of statistical methodologies that assume linearity of effect are justified for all factors except *costs*. The study also finds an unexpected positive slope from low costs to high costs. These two findings have implications for the design of future research studies on adoptions of IS innovations that include explicit costs as a factor. Thus, it may be better for future studies to either combine costs with quality (e.g., into a factor called *quality value*) or, if costs are used explicitly, to use non-linear techniques to assess the effect of costs.

The contributions to **IS practice** are, first, providing guidelines for archi-tecture vendors and the media on what factors they should focus on, when selling or discussing architectures. Thus, for example, the TCO debate described in section I, appears to include only costs.[9] In the face of these findings, a more meaningful debate might focus on the quality of software offered on competing architectures in the marketplace. Also, the results of this study indicate that vendors should emphasize the quality of software on their architectures, in their advertising, and in their product positioning. Second, the findings indicate to senior IS managers the factors that are considered by their peers when evaluating architectures for adoption by their organizations.

The results of this study indicate that software quality is the factor that needs to be considered in greater detail in future adoption studies of architectures. A follow-up CA study is being conducted where software quality has been decomposed into more refined factors: software reliability, learnability, response time, and feature set.

---

[9]In many cases, the TCO is used as a single quantitative measure that includes implicit costs also. In these cases, it appears that different agencies have attempted to include (and quantify) different factors, such as loss of productivity, in their TCO calculations. However, a meaningful comparison of TCO findings across agencies is not allowed, since each TCO study incorporates different intangibles, and, also, these intangibles are quantified using different assumptions. This study offers a listing of factors that should be included in such studies. The rigorous quantification of the factors in this study into a single measure is an issue for future research.

The results of a CA study using hypothetical products can also be mapped to actual products (in this case, architectures). If a rating of actual architectures is obtained (using, perhaps, a survey) on the levels of each factor, then the sum of the part worths for each actual architecture will reflect a ranking of the architectures in the eyes of senior IS managers and can be used to predict the degree of adoption of a particular architecture by organizations.

This study used a random sample from a population of large organizations, since the objective was to see if there are any patterns across large organizations. Another avenue for future work is designing a CA study by segmenting organizations into different populations and using a stratified sample. The stratification could be done based on organizational size, product type, organizational location, organizational structure, etc. This type of study can help identify patterns within strata, and differences across strata, regarding the adoption decision variables that relate to architectures.

VII. ACKNOWLEDGEMENTS

VIII. REFERENCES

Allen, B. R., and Boynton, A. C. "Information Architecture: In Search of Efficient Flexibility," *MIS Quarterly*, 1991, pp. 435-445.

Attewell, P. "Technology Diffusion and Organizational Learning: The Case of Business Computing," *Management Science* (3:1), 1992, pp. 1-19.

Best, J., and May, T. "Is Your Infrastructure Ticking?," *Information Management & Computer Security* (5:1), 1997, pp. 3-6.

Bray, P. "Making It Add Up," *Which Computer?* January 1994, pp. 36-42.

Broadbent, M., and Weill, P. "Management by Maxim: How Business and IT Managers Can Create IT Infrastructures," *Sloan Management Review*, Spring 1997, pp. 77-92.

Broadbent, M., Weill, P., O'Brien, T., and Neo, B. S. "Firm Context and Patterns of IT Infrastructure Capability," in *Proceedings of Seventeenth International Conference on Information Systems*, J. I. DeGross, S. Jarvenpaa, and A. Srinivasan (eds.), Cleveland, OH, 1996, pp. 174-194.

Chau, P. Y. K., and Tam, K. Y. "Factors Affecting the Adoption of Open Systems: An Exploratory Study," *MIS Quarterly*, March 1997, pp. 1-23.

Cornell, G., and Horstmann, C. S. *Core Java*, *Java Series*, Mountain View, CA: The SunSoft Press, 1996.

Ditsa, G. M., and MacGregor, R. C. "Our Mousetrap's Fine: So Why Aren't People Beating a Path to Our Door?," *Information Resources Management Journal,* Summer 1997, pp. 28-39.

Dos Santos, B. L., and Pfeffers, K. "Rewards to Investors in Innovative Information Technology Aplications: First Moovers and Early Followers in ATMs," *Organization Science* (6:3), 1995, pp. 241-259.

Ettlie, J. E., Bridges, W. P., and O'Keefe, R. "Organization Strategy and Structural Differences for Radical versus Incremental Innovation," *Management Science* (30), 1984, pp. 682-695.

Fichman, R. G. "Information Technology Diffusion: A Review of Empirical Research," in *Proceedings of the Thirteenth International Conference on Information Systems*, J. I. DeGross, J. Becker, and J. Elam (eds.), Dallas, TX, 1992.

Francis, R., and Johnston, S. J. "How Much Will It Cost?," *Information Week*, March 3, 1997, pp. 44-46.

Glaser, B. G., and Strauss, A. L. *The Discovery of Grounded Theory*, Chicago: Aldine Publishing Co., 1967.

Gordon, S. R., and Gordon, J. R. "Factors that Affect the Adoption of Distributed Database Systems," in *Proceedings of the ACM SIGCPR Conference*, M. R. Tanniru (ed.), St. Louis, MO, 1993.

Green, P. E., and Rao, V. R. "Conjoint Measurement for Quantifying Judgmental Data," *Journal of Marketing Research* (8), August 1971, pp. 355-363.

Green, P. E., and Srinivasan, V. "Conjoint Analysis In Consumer Research: Issues and Outlook," *Journal of Consumer Research* (5), September 1978, pp. 103-123.

Grover, V., and Goslar, M. D. "The Initiation, Adoption and Implementation of Telecommunications Technologies in U.S. Organizations," *Journal of Management Information Systems* (10:1), 1993, pp. 141-163.

Hair, J. F. *Multivariate Data Analysis with Readings* (3rd ed.), New York: Macmillan Publishing Co., 1992.

Howell, J. M., and Higgins, C. A. "Champions of Technological Innovation," *Administrative Science Quarterly* (35), 1990, pp. 317-341.

Johnston, S. J., and Francis, R. "PC Vendors Fight Back," *Information Week*, February 24, 1997, pp. 14-15.

Jones, R. "Count the Cost (PCS)," *Personal Computer Magazine,* April 1992, pp. 170-171, 173.

Katz, M. L., and Shapiro, C. "Technology Adoption in the Presence of Network Externalities," *Journal of Political Economy* (94), 1986, pp. 822-841.

Keen, P. G. W. *Shaping the Future: Business Design Through Information Technology*, Boston: Harvard Business School Press, 1991.

King, J. L. "Centralized versus Decentralized Computing: Organizational Considerations and Management Options," *Computing Surveys* (15:4), 1983, pp. 319-349.

Kwon, T. H., and Zmud, R. W. "Unifying the Fragmented Models of Information Systems Implementations," in *Critical Issues in Information Systems Research*, R. Boland and R. Hirschheim (eds.), Chichester, UK: John Wiley & Sons, Ltd., 1987, pp. 227-252.

Lind, M. R., Zmud, R. W., and Fischer, W. A. "Microcomputer Adoption: The Impact of Organizational Size and Structure," *Information & Management* (16), 1989, pp. 157-162.

Luce, D. R., and Tukey, J. W. "Simultaneous Conjoint Measurement: A New Type of Fundamental Measurement," *Journal of Mathematical Psychology* (1), February 1964, pp. 1-27.

Markus, M. L. "Towards a Critical Mass Theory of Interactive Media: Universal Access, Interdependence and Diffusion," *Communications Research* (14), 1987, pp. 491-511.

Markus, M. L., and Keill, M. "If We Built It, They Will Come: Designing Information Systems that People Want to Use," *Sloan Management Review* (35:4), 1994, pp. 11-25.

Moore, G. C., and Benbasat, I. "Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation," *Information Systems Research* (2:3), 1991, pp. 192-222.

Nunnally, J. C. *Psychometric Theory*, New York: McGraw Hill, 1978.

Pervan, G. "How Chief Executive Officers in Large Organizations View the Management of Their Information Systems," *Journal of Information Technology* (13), 1998, pp. 95-109.

Phillips, J. "The Choice Is Yours [Network Computers]," *Network News*, January 15, 1997, pp. 29-33.

Pierce, J. L., and Delbecq, A. L. "Organization Structure, Individual Attributes and Innovation," *Academy of Management Review* (2), 1977, pp. 27-37.

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

Swanson, E. B. "Information Systems Innovation Among Organizations," *Management Science* (40:9), 1994, pp. 1069-1092.

Thong, J., and Yap, C. S. "CEO Characteristics, Organizational Characteristics and Information Technology Adoption in Small Businesses," *Omega, International Journal of Management Science* (23:4), 1995, pp. 429-442.

Tornatzky, L. G., and Klein, K. J. "Innovation Characteristics and Innovation Adoption-Implementation: A Meta-Analysis of Findings," *IEEE Transactions on Engineering Management* (EM-29:1), 1982, pp. 28-45.

Wittink, D. R., Krishnamurthi, L., and Reibstein, D. J. "The Effect of Differences in the Number of Attribute Levels on Conjoint Results," *Marketing Letters* (1:2), 1990, pp. 113-29.

Wonnacott, T. H., and Wonnacott, R. J. *Introductory Statistics for Business and Economics* (3rd ed.), New York: John Wiley & Sons, Inc., 1984.

Wyner, G. M., and Malone, T. W. "Cowboys or Commanders: Does Information Technology Lead to Decentralization?," in *Proceedings of the Seventeenth International Conference on Information Systems*, J. I. DeGross, S. Jarvenpaa, and A. Srinivasan (eds.), Cleveland, OH, 1996.

Zmud, R. W. "An Examination of 'Push-Pull' Theory Applied to Process Innovation in Knowledge Work," *Management Science* (30:6), 1984, pp. 727-738.

Zmud, R. W., Boynton, A. C., and Jacobs, G. C. "An Examination of Management Strategies for Increasing Information Technology Penetration in Organizations," in *Proceedings of Proceedings of the Eighth International Conference on Information Systems*, J. I. DeGross and C. H. Krlebel (eds.), Pittsburgh, PA, 1987.

IX. ABOUT THE AUTHOR

Akhilesh Bajaj is an assistant professor of Information Systems Management at the John H. Heinz III School of Public Policy and Management, Carnegie Mellon University. He has a B.Tech. from the Indian Institute of Technology, Bombay, an M.B.A. from Cornell University and a Ph.D. in MIS from the University of Arizona. Akhilesh's research interests include the creation and evaluation of models that help in constructing large scale organizational information systems and the study of decision models used by consumers when they evaluate information systems.

APPENDIX A

The 20 hypothetical architectures (16 for the orthogonal set plus four holdout) generated by SPSS:

Architecture Name	Backward Compatibility Level	Software Quality Level	Centralized/ Distributed Level	Costs Level	Acceptance of the Architecture Level
Architecture A	Medium	Medium	Centralized	Medium	Low
Architecture B	Low	Low	Centralized	Low	Low
Architecture C	High	Medium	Distributed	Low	Medium
Architecture D	High	High	Distributed	High	Low
Architecture E	Medium	Low	Distributed	Low	Low
Architecture F	Low	Low	Distributed	Low	Low
Architecture G	Low	Medium	Centralized	High	Low
Architecture H	Medium	Low	Distributed	High	High
Architecture I	Low	Medium	Distributed	Low	High
Architecture J	Low	High	Distributed	Medium	Low
Architecture K	Low	High	Centralized	Low	High
Architecture L	Low	Low	Centralized	High	Medium
Architecture M	Low	Low	Distributed	Medium	Medium
Architecture N	Medium	High	Centralized	Low	Medium
Architecture O	High	Low	Centralized	Low	Low
Architecture P	High	Low	Centralized	Medium	High
Architecture Q	High	Low	Centralized	Medium	Low
Architecture R	Low	High	Distributed	Low	High
Architecture S	Medium	Medium	Distributed	Low	Low
Architecture T	High	High	Centralized	Medium	Low

APPENDIX B

DESCRIPTION OF THE STUDY PACKET

Demographic Information

1.   Name:

2.   Organizational Address:

3.   Organizational Position and Duties:

4.   Years of Experience in the IS Area:

5.   Highest Educational Degree:

6.   Gender:

7.   What best describes the computing environment you feel most comfortable managing (circle one, please):

Mainframe-based Systems	Client Server Systems	Intranet-based Systems	Fully Distributed Systems

Please read the following *carefully* in order to understand the study.

This study looks at what issues IS managers like yourself consider when selecting *computing architectures* for your organization. There are several computing architectures that are available. Examples of computing architectures include:

•   mainframe systems with terminals,

•   client server systems (client and server machines dividing up the processing,

•   the proposed architecture of diskless network computers running off an intranet server, and

•   a fully networked architecture, where each machine is a server by itself, and communicates with every other machine.

A computing architecture gives rise to a large number of hardware products, as well as software. In many cases, it has profound effects on how organizations conduct their business, since the software and hardware the organization uses changes with the architecture. For example, an architecture shift from mainframe to client server systems significantly changed the software and hardware that end-users use.

In this study, we assume that a computing architecture is *completely described* by the following *factors*:

1. **Software quality**: The quality of software associated with the architecture. This can include response time to end users, quality of the user interface, and features provided by the software, etc. Since users interface with the system via software, overall, this factor could play an important role in determining how satisfied end-users are with the software and the system.

    In this study, a computing architecture's software quality has one of three levels: **low**, **medium**, or **high**.

2. **Centralization vs. distributed nature:** Some computing architectures are inherently more centralized than others. A centralized architecture means that software resides in a centralized location and most of the hardware investment is also centralized. Thus, a mainframe architecture and an intranet architecture with network computers are centralized. The client server architecture and the fully distributed architecture are distributed, that is: the software and hardware investments are scattered on user machines. A centralized architecture is usually easier to maintain, while a distributed architecture usually provides greater freedom to end-users in terms of being able to install their own local software, etc.

    In this study, a architecture is either considered **centralized** or **distributed**.

3. **Costs:** Each computing architecture comes associated with its own costs. The costs include the costs of acquisition of hardware/software, the cost of maintenance of hardware, the costs of controlling different versions of software, the availability of people trained in the maintenace of hardware/software of the computing architecture, and so on.

    In this study, a architecture can have **low**, **medium**, or **high** costs associated with it.

4. **Acceptance of the architecture:** This factor represents the degree to which a particular computing architecture has been accepted by IS magazines, the media, model organizations you look up to, software vendors who write software that you use, etc. This factor can influence how senior managers

like the CEO, CFO, etc., in your organization feel about the architecture (they are more likely to buy into an accepted architecture). An architecture with low acceptance is not necessarily bad; it could just be new.

In this study, a architecture can have **low**, **medium**, or **high** acceptance.

5. **Backward compatibility of architecture:** This factor models the degree to which a computing architecture will cause changes in your organization. The changes can be of many types; for example, the ability to have your organization's existing information read by software in the new architecture, the need to retrain users in the new software of the architecture (maybe the word processor and spreadsheets look different), the learning curve of your IS staff in maintaining the hardware/software in the architecture, etc. This factor can also be important in determining the initial satisfaction of your end users and IS staff.

In this study, a architecture can have a **high**, **medium**, or **low** backward compatibility.

You will now be presented with 20 different computing architectures. These architectures do not have names, but are arbitrarily labeled from A to T. *Each architecture will be described in terms of the five factors we just discussed*. As an IS manager, we would like you to do the following:

• Please sort these 20 architectures (on the 20 different cards) in descending order of preference (from most preferred on the top of the pile to least preferred at the bottom).

• After you have sorted the cards, please write a number on each card that gives a numerical value to your preference, from 1 to 100. The least preferred architecture (at the bottom of the pile) will be given a score of 1, while the most preferred architecture will be given a score of 100. The cards in between should be given a preference score (between 1 and 100). Naturally, each card should have a preference score lower than the card above it, and higher than the card below it. *However, the scores need not be spaced equally*. It is entirely up to you to choose the score you wish to give each architecture. Note that the *entire architecture should be given one preference score* based on how appealing it is to you.

Also, in case you change your preferences, you may reorder the cards in the heap at any time during the study. If you do alter the order, please make sure you alter

the preference scores as well, i.e., the preference score of every card is still between the scores of the cards above and below it.

Since we shall be re-using the cards, please use the pencil provided to write on the cards. All the factors discussed earlier have been summarized on a single sheet, for your convenience. Please feel free to refer to this.

Below is an example of one architecture on a card. In all, the packet had 20 cards, one for each architecture. Note that in this packet, the *centralized/distributed* factor is listed first for all the cards. There were four other packets created, each having a different order of factors.

<div style="border:1px solid black; padding:1em;">

Architecture A

Centralized/Distributed: <u>Centralized</u>

Costs: <u>Medium</u>

Acceptance of the Architecture: <u>Low</u>

Backward Compatibility of the Architecture: <u>Medium</u>

Software Quality: <u>Medium</u>

</div>

APPENDIX C

The numbers for Figures C1 through C5 are presented in Table C1. Here, *Acceptl* implies the factor acceptance with level "low," etc. Figures C1 through C5 show the individual level decision models for the senior IS managers who participated in the study.

The relative worth parts for each factor (for each subject) are presented in Table C2.

Table C1. The Dummy Variable Coefficients for Each Level
of Each Factor for Each Subject

Subject	Acceptl	Acceptm	Accepth	BCl	BCm	BCh	SQl	SQm	SQh	Cent	Dist	Costsl	Costsm	Costsh
1	-23.2	1	22.25	-4.75	-1.87	6.625	-24.5	2.666	21.91	1.437	-1.43	2.25	2.875	-5.15
2	-8.25	7.75	0.5	-5.91	1.083	4.833	-48.4	23.95	24.45	0.312	-0.31	6.416	-2.08	-4.33
3	-9.16	-2.41	11.53	-1.83	0.166	1.66	-20.8	6.916	13.91	-12	12	-0.16	17.08	-16.9
4	-3.25	2.375	0.875	-0.41	2.83	-2.41	-12.9	-4.04	16.95	14.43	-14.4	14.08	10.45	-24.5
5	-1.08	-1.95	3.041	-7.91	-5.16	13.0	-28.4	7.958	20.45	11.31	-11.3	3.25	-0.62	-2.62
6	6	-5	-1	-0.66	-4.16	4.833	-17.5	2.12	15.37	-24.5	24.5	1.166	2.041	-3.20
7	-6	-4.12	10.12	-6.33	-5.20	11.54	-41.1	17.08	24.08	9.375	-9.37	7.33	10.20	-17.5
8	-6.08	-4.70	10.79	-10.0	1.041	9.041	-6.75	-0.62	7.37	-15.1	15.18	-29.0	21.54	7.541
9	-22.5	12.12	10.37	-10	7	3	-27	9.75	17.25	8.5	-8.5	17.5	0.375	-17.8
10	2.416	1.916	-4.33	-15.9	3.833	12.08	-36.0	11.29	24.79	6.437	-6.43	10.75	4.75	-15.5
11	-8.25	-9.25	17.5	0.583	10.45	-11.0	-38.5	4.91	33.66	-5.18	5.18	0.583	7.458	-8.04
12	0.416	0.416	-0.83	-7.41	-0.79	8.208	-29.5	-3.33	32.91	3.562	-3.56	7.25	0.375	-7.62
13	3.08	-1.66	-1.41	0.416	-12.8	12.41	-28.7	0.125	28.62	-15.8	15.81	-4.58	3.416	1.166
14	-2.83	10.79	-7.95	-14.8	7.291	7.541	-36	8	28	1	-1	3.833	-3.29	-0.54
15	-40.5	15.75	24.75	-12.5	0	12.5	-5.5	3.75	1.75	-2.37	2.375	-3.5	3.5	0
16	-6.08	3.666	2.416	-6.58	2.791	3.791	-40.2	5.125	35.12	-0.81	0.812	2.25	-0.5	-1.75
17	1.5	1.5	-3	-4.33	1.291	3.041	-20.8	6.666	14.16	24.62	-24.6	-3.5	3.5	0
18	-37.2	6.75	30.5	-8.75	2.125	6.625	-18.0	7.79	10.2	-4.93	4.937	8.75	-2.25	-6.5
19	-0.16	4.70	-4.54	-8	2	6	-32.5	-3.3	35.87	-9.5	9.5	2.66	0.416	-3.08
20	-1.5	2.875	-1.37	-5	-2	7	-23.5	-2.12	25.62	19.12	-19.1	0	-5.25	5.25
21	-15.9	4.458	11.45	-13.0	9.916	3.166	-29.2	21.87	7.375	12.81	-12.8	10.41	-6.45	-3.95
22	-11.0	-6.20	17.29	-10.0	8.541	1.541	-18.9	10.08	8.833	18.68	-18.6	5.08	13.33	-18.4
23	-0.66	6.083	-5.41	-9	6.25	2.75	-27.6	1.583	26.08	-4.87	4.875	11.33	7.583	-18.9

Table C2. Relative Part Worths of the Five Factors for Each Subject

Subjects	Acceptance	Backward Compatibility	Software Quality	Centralization/ Distribution	Costs
1	39.82	9.96	40.70	2.52	7.00
2	14.41	9.68	65.65	0.56	9.68
3	17.74	2.99	29.70	20.51	29.06
4	5.20	4.85	27.60	26.67	35.68
5	4.84	20.31	47.28	21.89	5.68
6	10.27	8.40	30.69	45.74	4.90
7	11.06	12.26	44.77	12.86	19.04
8	12.87	14.59	10.77	23.16	38.61
9	24.00	9.01	30.68	11.79	24.52
10	5.01	20.78	45.18	9.55	19.48
11	18.27	14.69	49.36	7.09	10.59
12	1.23	15.41	61.65	7.03	14.67
13	3.74	19.88	45.18	24.90	6.30
14	16.41	19.58	56.02	1.75	6.24
15	58.65	22.47	8.31	4.27	6.29
16	9.64	10.26	74.54	1.61	3.96
17	4.36	7.15	33.94	47.76	6.79
18	49.59	11.25	20.77	7.23	11.16
19	7.95	12.03	58.75	16.33	4.94
20	3.83	10.50	43.00	33.48	9.19
21	19.01	15.97	35.50	17.80	11.72
22	19.55	12.83	19.98	25.75	21.88
23	9.54	12.66	44.61	8.09	25.10
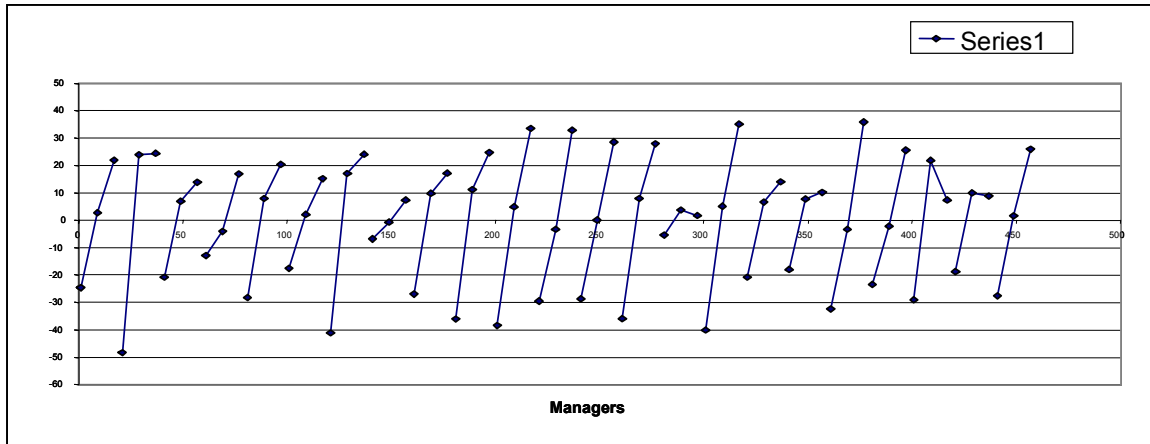
Figure C1. Dummy Variable Coefficients for Software Quality for Each IS Manager
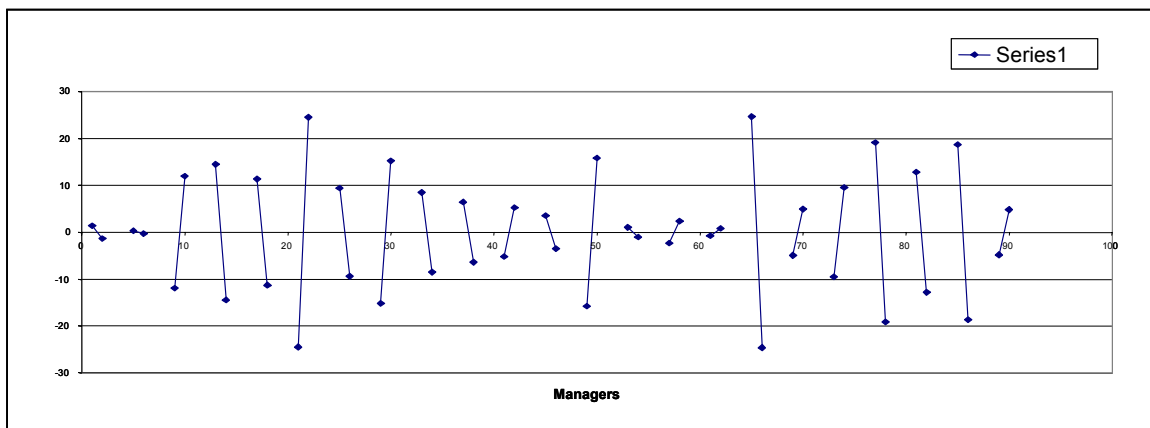
Figure C2. Dummy Variable Coefficients for Cost for Each IS Manager
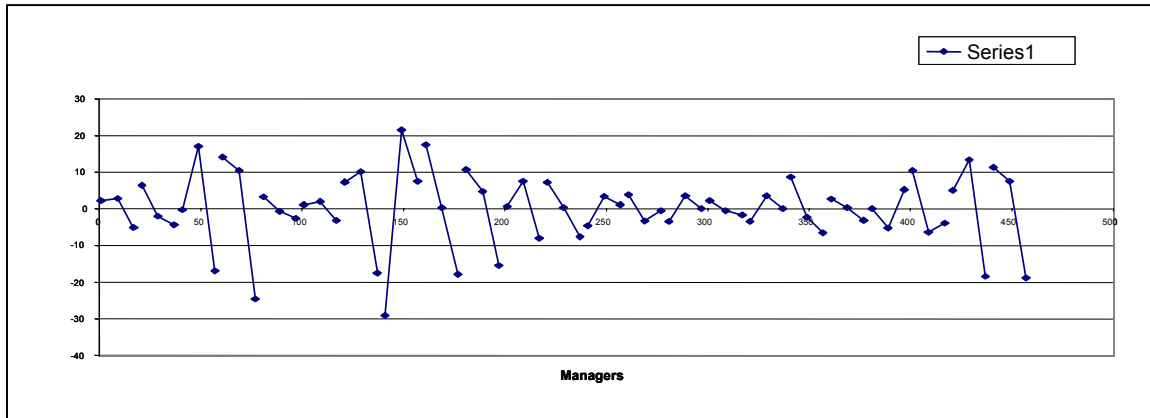
**Figure C3. Dummy Variable Coefficient for Cost
for Each IS Manager**
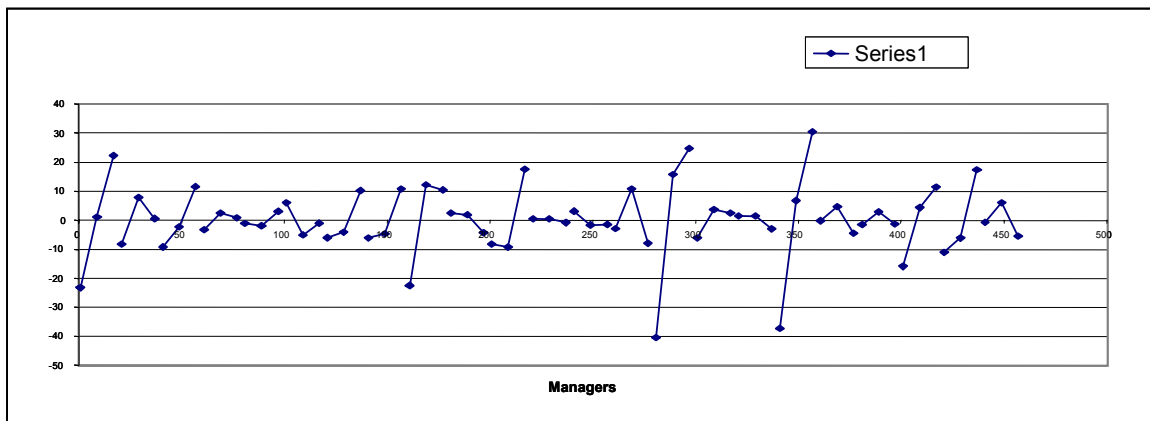
**Figure C4. Dummy Variable Coefficients for Acceptance
for Each IS Manager**
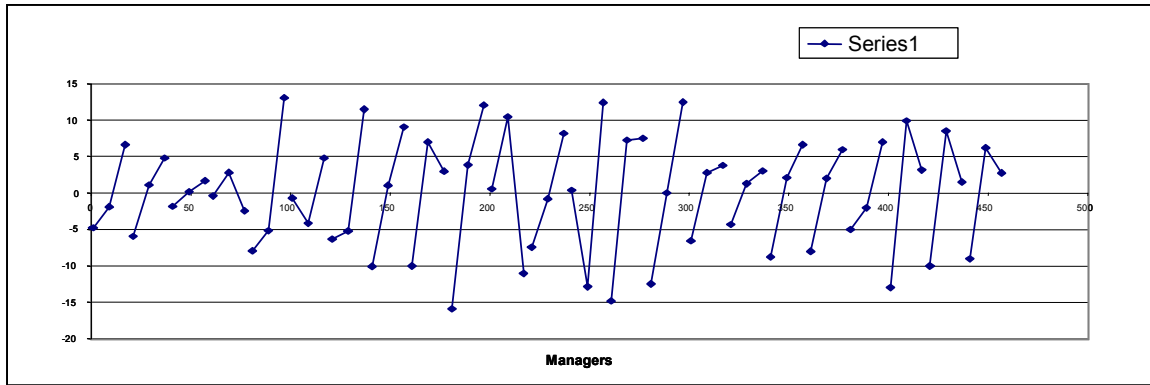
**Figure C5. Dummy Variable Coefficients for Backward
Compatibility for Each IS Manager**

APPENDIX D

DEVELOPING A CA-BASED METHODOLOGY FOR IS STUDIES

CA is related to traditional experimentation, in which the effects of levels of independent variables are determined on a dependent variable, for example, the effects of temperature and pressure on the density of soap in a soap manufacturing process. In situations involving human behavior, such as in IS, we want to also determine the effects of levels of certain variables (equivalent to independent variables) on the dependent variable, which is often an overall rating or a purchase decision or an adoption decision. However, the "independent variables" in human behavior studies are often weakly measured or qualitatively specified (Green and Srinivasan 1978). An example in IS would be whether a system is decentralized or centralized and the effect of this variable on an overall evaluation (the dependent variable).

The basic model in a CA study is:

$$Y_1 = X_1 + X_2 + X_3 + ... + X_n$$
(*metric* or *non-metric*)[10]   (*non-metric*)

The main advantages of CA from a statistical perspective are its ability to accommodate metric or non-metric dependent variables, its ability to use non-metric variables as predictors and the quite general assumptions about the relationships of the independent variables with the dependent variable (e.g., no linearity assumptions are made) (Hair 1992). A CA study has two main objectives. First, to determine the contributions of various predictor variables (also called attributes) and their respective values (or levels) to the dependent variable (usually an overall evaluation of a product or concept) and, second, to establish a predictive model for new combinations of values taken from the predictor variables.

---

[10]Metric refers to an interval or ratio scale, while non-metric refers to a nominal or ordinal scale.

CA is based on the premise that subjects evaluate the value or utility of a product/service/idea (real or hypothetical) by combining the separate amounts of utility provided by each attribute. CA is a **decompositional** technique, because a subject's overall evaluation is decomposed to give utilities for each predictor variable, and indeed for each level of a predictor variable. The overall relative utility for each predictor variable or attribute is called the part-worth of that attribute. CA is common in behavioral studies (Luce and Tukey 1964) and in marketing studies (Green and Rao 1971), where the predictor variables are often called **attributes** and the dependent variable is often an overall evaluation of a product.

Several works highlight CA in detail (Hair 1992; Luce and Tukey 1964; Wittink et al. 1990). Without substituting for them in any way, a simple description is presented here of the essential concepts in a CA study. For a CA study, a **product class** is considered, along with a set of subjects who would evaluate products in that class. A set of **attributes** (predictor variables) is selected to describe the product class. The possible **levels** of each attribute are selected. A **product** in the product class is then simply a **combination of attribute levels** (one level per attribute).

The method of **data collection** in the CA study can be face-to-face, which is more time consuming but allows for a richer operationalization of each attribute, or by mail, which allows for greater reach of subjects but permits leaner operationalizations in the interests of validity. A face-to-face data collection method, such as used in the current study, represents potentially a happy medium between a case study (where the operationalization is very rich but validity is often criticized) and a simple Likert scale survey questionnaire, where the operationalization is very lean, although validity is quantifiable, using techniques such as factor analysis and Cronbach's alpha (Nunnally 1978). The method of **data analysis** depends on whether the dependent variable is metric (in which case categorical variable regression can be used) or non-metric (in which case logistic regression or discriminant analysis can be used). A further choice facing the researchers is the

composition rule to be used: additive or with interactive effects. For most situations where a predictive model is desired, and where the attributes involve less emotional or aesthetic judgments and are tangible (as is reasonable to assume in IS), an additive model is usually sufficient (Hair 1992)

From an application perspective, the CA methodology has several advantages. First, it permits the construction of utility models in application areas where the predictor variables are often weakly quantifiable, as in the case of studies involving perceptions, which are commonplace in IS research.

Second, a CA study allows for a more realistic overall decision model for a population, because it forces subjects to evaluate the products as a whole (as in real life). It forms individual decision models for each subject. These models can be tested for internal validity by using a hold out sample (a set of products in the product class whose predicted evaluations are compared with the subject's actual evaluations). It allows the formation of an aggregate decision model across all of the subjects and permits the statistical testing of the null hypothesis that all of the attributes have an equal utility in the aggregate decision model.

Third, CA makes no assumptions about the nature of the relationships between the attributes and the dependent variable. This makes it very useful when exploring unknown variables as potential predictors.

OPERATIONALIZING AND SELECTING LEVELS AND SCALES FOR THE PREDICTOR VARIABLES (ATRIBUTES)

The responses in a CA study are very dependent on the way the attributes and the scales (the number of levels and the range of the levels for an attribute) are presented to the subjects. If attributes are chosen that are prima facie known to be of less importance than others, then that will certainly affect the outcome. So, if we know before hand that, let's say, *backward compatibility*, as defined and scaled for the subjects, is not likely to be as important as, let's say, *cost*, as defined and scaled, then that is probably what the outcome will be. What is needed in a study that seeks to assess relative part worths of each attribute is to operationalize the

attributes (which are qualitative concepts) in such a way that their importance for the subjects are prima facie the same, as they are presented and scaled in the study. This will allow the study to be conducted as a classical hypothesis test, with the null hypothesis being that the relative part worths of all attributes (predictor variables), **as they are scaled**, are equal.

Another issue with operationalization deals with construct validity: i.e., first, do all the subjects have a reasonably consistent idea of each attribute and its scaling and, second, is this idea the same as what the researchers think it is. So a faulty operationalization will leave different subjects interpreting the constructs (or attributes) differently, while a better operationalization will mean that different subjects view the attributes and their scales in the same way.

One way to ensure construct validity and allow realistic scaling, is to ask a sample in the subject population itself to define the predictor variables. This technique allows the researcher to define the predictor variables (attributes) in a manner uniformly understandable to the subjects and also to identify realistic end-points of the scales used for the attribute levels. This has been done in this study.

HYPOTHESIS TESTING AND SAMPLE SIZE ISSUES IN A CA STUDY

As mentioned in the paper, the CA study can be constructed as a classical hypothesis test, with the null hypothesis being that the part worths of all the attributes are equal. In order to test such a hypothesis, we proceed as follows. First, individual decision models for each subject in the sample are constructed. These individual decision models give the part worths of each attribute for each subject. In this study, Table C2 in Appendix C shows this information. Once the part-worths of each subject in the sample are obtained, they can be aggregated to get a **mean** part worth for each factor for the sample. The mean value and the variance are then sufficient to statistically test the null hypothesis. The regular caveats of using too **large** a sample size apply. Thus, several basic statistical text books on hypothesis

testing (e.g., Wonnacott and Wonnacott 1984) caution against using too large a sample size, because that would indicate statistical validity for even small differences in means—differences that may not be actually significant for the situation under study. The sample size[11] is closely related to the degrees of freedom in the test and a small sample size indicates fewer degrees of freedom, leading to a wider confidence interval. Thus, statistical validity from a smaller sample size (as long as the sample is random) is a good indicator that some real differences in the means have been found. In this study, a sample size of 23 was used and statistically valid differences were obtained between some of the means (thus disproving the null hypothesis of the study).

The steps to be used in a CA study for an IS are summarized in Figure D1.

---

1. Identify the product or concept of interest as a product class. Identify attributes important in the decision space when making evaluation decisions.

2. Select appropriate levels for each factor (a.k.a. attribute or predictor variable).

3. Operationalize each factor in a manner suitable for the data collection technique being used.

4. Create study packet and pilot test for clarity of measures, time taken for one study, any other implementation problem or possible biases.

5. Select random samples of subjects from population.

6. Administer the study to the subjects.

7. Analyze data, test hypotheses, and present results.

Figure D1. List of Steps that Constitute a CA Study

---

[11]We are assuming a random sample here.

EDITOR
Phillip Ein-Dor
Tel Aviv University

JAIS EDITORIAL BOARD

ADMINISTRATIVE PERSONNEL