Innovation Characteristics and Innovation Adoption-Implementation: A Meta-Analysis of Findings

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Abstract—**A review and meta-analysis was performed of seventy-five articles concerned with innovation characteristics and their relationship to innovation adoption and implementation. One part of the analysis consisted of constructing a methodological profile of the existing studies, and constrasting this with a hypothetical optimal approach. A second part of the study employed meta-analytic statistical techniques to assess the generality and consistency of existing empirical findings. Three innovation characteristics (compatibility, relative advantage, and complexity) had tbe most consistent significant relationships to Innovation adoption. Suggestions for future research in the area were made.**

INTRODUCTION

INNOVATION characteristics research describes the relationship between the attributes or characteristics of an innovation and the adoption or implementaion of that innovation. This topic represents one of the classic issues in the innovation literature, albeit one that has been little studied in the last decade. As an area of considerable past activity, it has been reviewed (Rogers and Shoemaker, 1971; Rothman, 1974; Zaltman and Lin, 1970) and critiqued (Downs and Mohr, 1976) previously. While both Rogers and Shoemaker's and Rothman's reviews are quite comprehensive, their respective analyses of the literature largely exclude any detailed examination of the reviewed studies' methodological or conceptual rigor. But, nonetheless, it is on the basis of such general (not detailed methodological) reviews that others, especially Downs and Mohr, have criticized innovation characteristics research as a body of inquiry.

This paper presents the results of a comprehensive literature review and preliminary meta-analysis of studies of innovation characteristics. In order to supplement earlier reviews, we provide a methodological and conceptual profile of innovation characteristics literature. The study is also designed to examine the extent to which Downs and Mohr's criticisms are appropriate. Finally, we provide our own recommendations for the future study of innovation characteristics.

Before turning to the methods, results, and discussion of this meta-analysis, further discussion of Downs and Mohrs' criticism of the innovation characteristics literature and also our own observations for the ideal innovation characteristic study are in order.

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The Downs and Mohr Critique

In their review of the innovation literature, Downs and Mohr (1976) devote considerable attention to what they see as fatal flaws in the studies of innovation characteristics. According to Downs and Mohr, this body of research focuses on both *primary* and *secondary* attributes of innovations but fails to pay sufficient attention to the distinction between the two. Primary attributes are seen as inherent to the innovation or technology and invariant across settings and organizations; secondary attributes are defined as perceptually based (or subjective) characteristics. An example of a so-called primary attribute is size or cost. Complexity or relative advantage are secondary attributes. Perception of secondary attributes is assumed to be influenced by characteristics of both the particular setting and the actors involved in implementing a particular innovation.

If anything, Downs and Mohr (1976) probably underplay the importance of "subjective" factors. Downs and Mohr ignore the perceptual literature in social psychology and related fields which has for many years noted that even what is assumed to be invariant physical reality (e.g., a primary attribute) is always subject to social influences. For example, group conformity studies demonstrated that respondents make startling alterations in perceptions of physical dimensions (Asch, 1956) when confronted with a synthetic majority opinion to the contrary.

Furthermore, while so-called primary attributes of innovations can be measured "objectively," the meaning of the objective measure of the characteristic is subjective, that is, in the mind of the perceiver. Thus while an innovation may cost a fixed amount (and cost is a so-called primary attribute), the cost of the innovation is evaluated by the potential adopter relative to his or her financial resources. The innovation's cost may seem inexpensive to one, exorbitant to another. In this sense, there can be no primary attribute of an innovation. Perceptions are always evaluated in reference to some internalized system of values or cognitive framework; the result is a subjective rating of the significance of the "fact" (e.g., size, cost, etc.) In any case, Downs and Mohr do rightly point out that "most if not all characteristics upon which one might consider basing a typology turn out to be secondary attributes of innovations" (p. 703).

More important for this discussion than the distinction between primary and secondary attributes *per se* is the inference that these authors make as a result. Downs and Mohr's conclusion is that "because an innovation's classification in a secondary-attributed topology can vary from organization to organi-

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zation" (p. 704) (presumably because people and organizational cultures differ so widely), it is fruitless or premature to attempt to construct typologies of innovations (based on perceived characteristics) to be used to generalize across a large sample of organizations or sites. Downs and Mohr argue that innovation attributes are essentially interactive with features of the organization such that "an innovation might be seen as minor or routine by some organizations but as major or radical by others" (p. 704). Thus they say, it is unlikely that a given innovation attribute–say "complexity"–would have the same kind of relationship to innovation adoption and implementation across a large array of organizations or sites. In contrast, consistent relationships are likely only to be found in rather narrow typologies of settings–relationships that might be reversed in other typologies. It should be emphasized that Downs and Mohr are not hypothesizing mere order of magnitude changes across settings, but changes that are potentially *qualitative and perceptual reversals.*

The central question here is this: If one acknowledges the subjectivity of innovation characteristics, does that imply nearly a complete situational specificity of these attributes? In the context of a relatively homogeneous culture, how diverse are perceptual judgements about the same innovation? In more prosaic terms, are we (and our perceptions) more alike or more different?

Fortunately, these conceptual issues can be translated into empirical questions and research design options. Thus we can ask: Across an heterogeneous array of innovations, actors, and organizations, does the innovation characteristic–adoption relationship vary widely in magnitude or reverse itself? If the relationship does vary widely or reverse itself, then one perhaps can agree with Downs and Mohr in rejecting "the notion that a unitary theory of innovation exists" (p. 701). If, instead, the relationship is fairly consistent, then the notion of innovation attribute still has some utility as an integrating concept.

In contrast to Downs and Mohr, a working hypothesis of this study is that perceived innovation characteristics *can* predict the adoption and implementation of various innovations, and with some degree of consistency across various settings. In a major qualification to this statement, however, we also assume that the literature fails, to a considerable extent, to exploit this possibility because of methodological and conceptual problems in many of the innovation characteristic studies. In order to preview some of the failings of the literature we have identified what "ideal" innovation characteristics research might look like.

Ideal Innovation Attribute Studies

As Kuhn (1962) has pointed out, one of the characteristics of scientific endeavor is the development of an agreed-upon paradigm of gathering evidence. As will become clearer in the Results section, the innovation characteristics literature is particularly lacking in a consensus on method and approach. The purpose of this section is to take a tentative step toward providing such a methodological and conceptual yardstick against which existing studies may be compared. In order to test the ability of innovation characteristics variables to predict innovation adoption and implementation, an ideal study might include the following features:

a) Innovation characteristics research studies should predict, rather than simply explain in a post-hoc fashion, the critical events of the phenomenon: If prediction of innovation and adoption is the goal of this line of research, then the true predictive ability of a given innovation characteristic must be directly and explicitly tested by a longitudinal approach. From a research design perspective this means that assessment of an innovation attribute should be obtained prior to, or concurrently with, a decision to adopt the innovation(s). Retrospective innovation characteristic studies are particularly suspect. Given what is known about the social psychology of decision-making (Festinger, 1964), one would expect raters of an innovation's characteristics to rate the innovation favorably once they had adopted it. Adopters would rationalize their decisions by appraising the innovations favorably, even if they had not actually felt so positively prior to adoption, or even if the innovation had not performed as well as had been originally expected. Most retrospective data gathering approaches are likely to give a distorted view of "prediction."

b) Innovation characteristics research studies should focus on both adoption and implementation as the dependent variables, and not simply dichotomous yes/no adoption decisions: A major addition to the innovation literature has been to extend the process orientation to account for events after an explicit commitment has been made to utilize an innovation. Degree-of-implementation, or some equivalent measure of implementation, will vary widely across a group of adopting organizations. In this sense, adoption becomes an extremely insensitive measure of innovation. As Downs and Mohr (1976) rightly point out, "operationalizing innovation by the extent of implementation comes closer to capturing the variations in behavior that we really want to explain" (p. 709).

c) Model studies should utilize research approaches that are reliable, replicable, and permit some degree of statistical power: Surveys, secondary data analysis, and experiments may be methodologically adequate in this sense because they permit both replicability and some degree of cross-study comparability. In contrast, theoretical pieces, and the usual single-site qualitative case study cannot logically provide a basis for generalizing about the innovation process.

d) Ideal innovation characteristics studies should utilize replicable and potentially reliable measures of innovation characteristics as perceived by decision-makers: Unless other researchers can replicate a given study's operations and instrumentation, assessing the comparability of findings is a faint hope. Moreover, unless data are based on *participants'* perceptions questions can be raised about the validity thereof.

e) Innovation characteristics research should consider *several characteristics of the innovations examined:* More than one innovation characteristic must be studied at the same time in order to adequately evaluate the relative predictive power of innovation characteristics across characteristics and to consider their interrelationships. It is difficult to compare the predictive ability of different characteristics measured in different ways from different respondents. Campbell and Fiske's (1959) suggestions definitely apply here.

f) *Innovation characteristics studies should gather measures of innovation characteristics across several innovations, not a single innovation at a time:* When only one innovation is studied, the results may or may not be completely idiosyncratic to that innovation, but the question is moot because of limited data.

g) *Research in this area should study innovations that will be adopted by organizations, not by individuals operating alone, if such innovations and such organizations are the author's real interest:* It is not logical to attempt to generalize from the individual adoption process to the organizational innovation process as the two processes may in fact be quite different. As pointed out by Downs and Mohr, the "innovation decision design" ought to be the approach to gathering data, with an adopting unit or organization undergoing innovation(s) as the locus of data-gathering. Moreover, as suggested by Hage (1980) the most involved members of an adopting unit (the "dominant coalition") would be the most informed respondents.

In the remainder of this paper, particularly in the Results section, we will come back to this tentative prescription paradigm in evaluating the existing literature.

METHODS AND PROCEDURES

Sample

A total of 75 articles pertaining to innovation characteristics were identified through a search of the literature, from a larger sample of 105 references. The principle sources for these references were Rogers and Shoemaker (1971) which contributed a total of 35 references, Rothman (1974) which contributed an additional 15 references, Zaltman, Duncan, and Holbeck (1973) which contributed an additional 6 references, and Havelock (1971) which contributed 3 more references. (Several references cited by these and other authors as pertinent to innovation characteristics were read and discarded because we judged the articles to be irrelevant for our purposes, or redundant with another article by the same author. We also could not obtain a copy of four references cited in previous reviews.) Other citations were obtained from researchers working in the field, computer searches, and by consulting other reviews. See Innovation Characteristic References for a list of the reviewed articles.

The sample of articles, while perhaps not exhaustive, is representative of this body of work. We included every reference we could readily find. If we missed any relevant study, it was a matter of oversight, not intent. The level of research activity in this particular area has decreased considerably in the last eight years, dating to the publication of Rogers and Shoemaker's 1971 book. Only fifteen percent of the articles reviewed were written in the last eight years.

Coding Procedure

A standard coding protocol was developed for abstracting various articles (Appendix A). Two coders reviewed each article. The primary coder (KK) read the article in detail and assigned preliminary scores and entries for all items. A second coder (LT) then reviewed all the data and made corrections as appropriate. No measures of inter-rater reliability were compiled because the majority of coding items called merely for enumeration (e.g., number of characteristics studied) or recording of data.

The following are the most important items in the coding sheet that were scored.

Prediction: The studies were coded into two groups, predictive studies (that actually measured the innovation characteristics prior to the decision maker's actual decision to adopt the innovation), and retrospective studies (that involved measuring or assessing innovation characteristics after the actual adoption decision).

Adoption and Implementation (Dependent Variable): The dependent variable(s) was categorized as an index of adoption alone (i.e., a yes/no decision) or an index of both adoption and implementation (i.e., the adoption decision *and* an ordinal degree of implementation scale or at least some measure that attempted to account for post adoption behavior).

Design: This item noted the type of methodology used in the study—case study, field survey or interview, experiment, theory building, or secondary data analysis.

Measurement: The measurement of innovation attributes in each study was categorized according to whether the attributes were 1) rated by decision-makers themselves: 2) rated by expert judges not directly involved in the innovation process; 3) inferred by the author(s); 4) based on objective, secondary data, e.g., cost; or 5) were not measured at all. In terms of the previous discussion, replicability and operationalization would likely be high with types 1, 2, and 4, and low with types 3 and 5. In turn, questions could be raised about the appropriateness of data not derived from the participants (types 2, 3, and 4) in the innovation process.

Number of Characteristics: The number of innovation attributes or characteristics that were measured or discussed in the particular reference was also noted.

Number of Innovations: A subsample of the studies address more than one innovation at a time. This was noted.

Locus of Innovation: Of interest here was whether the "adopter" or the adopting unit was an individual or some larger aggregate such as an organization or firm, community, or even nation.

Empirical Findings and Statistical Tests: To the extent that data were subjected to statistical treatment or analysis, the discrete findings whether of a correlational or comparative nature were noted.

Data Analysis

Data analysis in the usual sense (of analyzing primary data) was not employed. The purpose of the study was to develop a methodological and substantive profile of the existing innovation characteristics literature. As a result, most of the findings are in the form of frequency counts and descriptive tables.

A secondary goal was to employ, as appropriate, meta-analytic techniques to the data that were available. Meta-analysis (Glass, 1978) is a set of techniques designed to take *N* studies in a research area and make summative statistical statements about the strength, and consistency, of a relationship examined in those *N* studies. The *N* for meta-analytic exercises is often comprised of a number of separate and somewhat dissimilar empirical studies.

There is, unfortunately, little agreement in the meta-analysis field on how to handle nonexperimental studies. While it is relatively easy, and theoretically sound, to obtain and compare "effect size," a measure of the difference between control and experimental groups in an experimental study (see Winer, 1971, pp. 428–430), correlational and regression studies are not so easily compared and summarized. One meta-analysis technique for correlational studies is to evaluate the consistency of the *direction* of correlational findings, without regard for magnitude or statistical significance of a single correlation. Each correlational finding then becomes an independent data point concerning a phenomenon.

The procedure used in this study was to calculate the binominal probability of the directionality of the correlation between the independent and dependent variables. Thus we noted the positive or negative correlation between a given innovation characteristic (the independent variable) and adoption or implementation (the dependent variable), and then calculated the binomial probability of obtaining the given ratio of positive to negative correlations under the null hypothesis of a 50–50 split between negative and positive findings (Siegel, 1956). Since all of the innovation characteristics literature make directional statements the statistical results reported here are all one-tailed.

This meta-analysis technique is certainly less than ideal. For instance, we are forced to eliminate those studies that do not report first-order correlations, rhos, or chi squares. (For example, given the intercorrelation of the innovation characteristics in a study involving several characteristics, it is impossible to ascertain, from the regression coefficients alone, the first-order relationship between a single independent variable and the dependent variable; multicollinearity of the independent variables may actual reverse their regression coefficient signs in the equation.) Thus we were unable to use the findings of several studies in the meta-analyses.

This procedure is still an improvement over the "voting method" of meta-analysis, in which studies are weighed on the basis of their conclusions alone exclusive of data in the usual sense of that term. At the very least, the technique employed here excludes from the "vote" those studies that provide no statistical results whatsoever. Previous reviews that used the voting method included, for example, archeological case studies in which the reported "findings" were the researcher's insights that may well have been based on little more than his or her knowledge of how the theory was supposed to work.

One final note is in order in defense of the procedures employed. It will be recalled that a major contention of Downs

TABLE I
A METHODOLOGICAL PROFILE OF STUDIES OF INNOVATION CHARACTERISTICS

DESIGN ATTRIBUTE	ACTUAL STUDIES				
1) Predictive vs. Retrospective Approach	Predicted Adoption or Implementation	Explained Adoption or Implementation in a Post Hoc Fashion	NA		
	2.7% (2)	90.7% (68)	6.7% (5)		
2) Dependent Variables	Adoption	Adoption And Implementation			
	93.3% (70)	6.7% (5)			
3) Design Methodology	Survey	Secondary Data Analysis	Experiment	Case Study	Theory
	54.7% (41)	20% (15)	1.3% (1)	17.3% (13)	6.7% (5)
4) Measure of Characteristics	Rated by Decision Makers	Rated by Expert Judges	Cost and Profit	Inferred	NA
	18.7% (14)	5.3% (4)	10.7% (8)	60% (45)	5.3% (4)
5) Number of Characteristics Considered	One Characteristic	2–5 Characteristics	6–9 Characteristics	10 or more Characteristics	
	46.7% (35)	36% (27)	10.7% (8)	6.7% (5)	
6) Number of Innovations Studied	one innovation	2–5 innovations	6–9 innovations	10 or more innovations	NA
	53.3% (40)	12% (9)	2.7% (2)	25.3% (19)	6.7% (5)
7) Nature of Adopting Unit	Organization	Individual	Other	NA	
	33.3% (25)	57.3% (43)	8% (6)	1.3% (1)	

and Mohr (1976) is that the inconsistency of studies will be manifested not only in the magnitude of relationships but in their directionality. Inconsistency in directionality seems a much more severe failing in a body of research than inconsistency in magnitude of effects. While the meta-analytic techniques employed in this study are insensitive to magnitude, they are sensitive to directionality and seem particularly appropriate to the conceptual issues raised concerning this literature.

RESULTS

Summary Findings

An Overview of the Field: Table I presents an overview of the innovation characteristics literature as indicated by our sample of that literature. Inspection of the table permits a comparison between the hypothetical "yardstick" study outlined above, and the actual innovation characteristics literature that we reviewed. The modal study in the innovation characteristics literature deviates significantly from that ideal study. In detail, the methodological profiles of the studies are as follows:

Prediction of Adoption: Only two of the studies reviewed used innovation characteristics measured at one point in time to relate to innovation adoption and/or implementation at a later point in time. One predictive study (Ostlund, 1974) focused on the adoption of consumer products. Subjects rated the consumer products before the products where introduced on the commercial market. These ratings of the innovation characteristics (relative advantage, compatibility, complexity, observability, trialability, and perceived risk) were used, in conjunction with personal characteristics of the subjects, in a discriminant analysis designed to predict actual purchase of the innovation(s) upon their commercial availability.

The other predictive study (Tornatzky, Fergus, Avellar, and Fairweather, 1980) was embedded in experimental research which attempted to implement a treatment innovation in a national sample of mental hospitals. Questionnaires given to hospital staff prior to the adoption decision and implementation provided data on the philosophical congruity (or compatibility) and program distinctiveness (or radicalness) of the innovation. Ratings of these two characteristics were correlated with the subsequent adoption/rejection decision and degree of innovation implementation in the hospitals. In a strict sense of the term this was not a predictive study but a postdictive one. However, measurement of perceived innovation characteristics did precede the period of adoption and implementation.

Dependent Variable: Almost all of the studies examined the relationship of innovation characteristics to adoption, not adoption *and* implementation, of the innovation. One study (Tornatzky *et al.*, 1980) actually measured implementation as one of the dependent variables, using a phone checklist delivered to the adopting hospitals 90, 180, 270, and 360 days subsequent to adoption. The checklist was used to measure the extent to which crucial features of the innovation were actually in place.

Four other studies also attempted, with varying degrees of success, to take into account implementation of the innovation. Ettlie and Vellenga (1979) attempted to use a inter-stage time lag model of innovation adoption (in which the last inter-stage time lag was from adoption to actual implementation), but ended up collapsing the five different time lags between stages into a single dependent variable of the mean time lag between stages. Even if they had used the full five-stage model, Ettlie and Vellenga would not have characterized the degree of implementaion so much as simply timed the lag between adoption and implementation.

Another study (Mansfield, 1963) provided a somewhat different measurement of implementation, but still one based on the adoption–implementation time lag. The dependent variable in the study (Mansfield, 1963) is the intrafirm rate of diffusion of the innovation, or how long it took the firm to increase its stock of diesel locomotives from 10 to 90 percent of their total locomotive stock.

The remaining two studies ostensibly examining implementations included a case study of the adoption, implementation, and subsequent rejection of a single innovation (Coe and Barnhill, 1967), and a study in which racial integration is the innovation, and different degrees of integration in different settings are discussed (Molotoch, 1969). Given the rather dubious approaches to "measurement" of degree of implementation, it is questionable how much these studies contribute to the literature.

All in all, the failure to use some measure of adoption *and* implementation as the dependent variables in all but five of the studies reviewed is a conceptual and methodological weakness in the literature. Conceptually, a focus on an adoption decision as a dependent variable ignores the fact of post-adoption variability in implementation. The failure to use degree-of-implementation as a dependent variable probably yields misleading correlations of innovation characteristics with innovation behavior. For example, correlations (between innovation attributes and adoption) of a given magnitude and sign may reverse in sign and change in magnitude when computed relative to implementation (Tornatzky *et al.*, 1980).

Design: Most studies (54.7 percent) employed surveys or interviews to gather data. Also common were secondary data analyses (20 percent) (e.g., analyses of previously collected cost and productivity data) and case studies (17.3 percent). Experiments and theoretical pieces were rare. In most of the studies reviewed, the adequacy of these methodologies, especially surveys, secondary data analyses, and experiments, was undermined by the use of poor measures to study too few of the characteristics of too few innovations.

Measurement: Relatively few of the studies (18.7 percent) investigated the innovation attributes by direct measurement of decision-makers' perceptions using a replicable measurement approach. More typically (or 60 percent of the time), the investigators *inferred* the extent to which an attribute was present. An example of inferring an innovation characteristic is provided in a study of the adoption of family planning methods among low socio-economic status women (Emerson, Gordon, Koike, and Speidel, 1968). In the study, the authors found that "the idea of a small family" (p. 1743) was accepted significantly more often among users of family planning than among nonusers. Thus family planning was considered particularly compatible (as a "characteristic") to adopters of birth control, the innovation studied. The tautology of this approach is obvious.

In a few studies, the attributes were rated by "expert" judges who were assumed to be representative of the actual individuals making adoption and implementation decisions. In these studies no data were provided to support this assumption.

Number of Characteristics Studied: The majority of the studies examined one or only a few characteristics in a given setting. For example, 46.7 percent of the studies considered only one characteristic. Such single characteristic studies are not particularly useful for the purpose of clarifying the relative predictive power of attributes. It is difficult to compare the predictive power of various attributes unless the attributes are examined and compared within a single study based on the same respondents.

Number of Innovations Studied: Only one innovation was investigated in 53.3 percent of the studies. Under these circumstances it is difficult to differentiate between the idosyncratic features of a single innovation and the true predictive power of the innovation attributes across innovations. This is, of course, particularly important in correlational studies in which the unit of analysis is the innovation and the N equals the number of innovations studied. Only 28.0 percent of the studies investigated more than six innovations at one time.

Locus of Innovations: The "adopter" in 57.3 percent of the studies was a single person operating in a nonorganiza-

TABLE II
NUMBER OF KEY FEATURES PRESENT IN INNOVATION CHARACTERISTIC STUDIES

Number of Features	Number of Studies	Percent of Studies
0	9	12%
1	16	21.3%
2	16	21.3%
3	13	17.3%
4	14	18.7%
5	5	6.7%
6	2	2.7%
7	0	0%
	Total: 75	Total: 100%

tional context (e.g., an individual farmer or doctor). The innovations examined in these studies include farming techniques (e.g., Brandner & Kearl, 1964; Danda and Danda, 1968; and Fliegal and Kivlin, 1966), television (Graham, 1954), home energy conservation methods (Leonard-Barton & Rogers, 1979) and medical practices of individual doctors (Menzel, 1960).

An additional 33.3 percent of the studies emphasized innovations having an organizational locus, for example, education innovations (Allan and Wolf, 1978; and Birkly, 1966), petroleum refining innovations (Bundgaard-Nelson and Fiehn, 1974) and transportation innovations (Ettlie and Vellenga, 1979). The remainder of the studies emphasized community-wide innovations or specified no particular innovation setting whatsoever.

Summary: No study captured the seven design features of the ideal paradigm sketched above. In fact, only two studies (Ettlie & Vellenga, 1979; Tornatzky *et al.*, 1980) had six of the seven features, and five studies had five of these features. A summary of these data is presented in Table II.

These studies represent considerable methodological and conceptual weaknesses in their execution. This fact ought to be juxtaposed against Downs and Mohr's (1976) assumption that the innovation process field is incapable of making aggregate and general statements about innovation processes because of the *inherent nature* of the phenomenon. Based on the data presented in Table I, and data to be presented below, a better conclusion might be that the lack of generalizability and inconsistency of findings in these studies is caused by a more mundane problem, poorly designed studies. Until these methods problems are resolved, only very tentative answers can be given to the conceptual questions.

DISAGGREGATED FINDINGS

In this section, we will attempt to disaggregate the picture presented in Table I by looking in greater detail at several of the innovation attributes that have occupied the attention of researchers. The following ten attributes are considered in detail: 1) compatibility, 2) relative advantage, 3) complexity, 4) cost, 5) communicability, 6) divisibility, 7) profitability, 8) social approval, 9) trialability, and 10) observability. These ten characteristics were the ten most frequently addressed in the articles reviewed. The order in which they are presented reflects the number of articles referring to each characteristic. It should be noted that thirty different characteristics were studied in the articles reviewed (Appendix B), a fact that raises serious questions about the independence of these dimensions.[1]

For each of the ten characteristics to be examined, the standard definition is given, and an overview of the quality of the relevant references in terms of methodology, measures, and the nature of the adopting unit. Finally, the discrete statistical findings regarding the relationship of the characteristics to innovation adoption and implementation are reviewed using the meta-analytic technique described above. All of this information is presented for each characteristic in tabular form paralleling Table I, with explanations as necessary in the text.

Compatibility

According to Rogers and Shoemaker (1971), the compatibility of an innovation is "the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of the receivers." Compatibility may refer to compatibility with the *values* or norms of the potential adopters or may represent congruence with the existing *practices* of the adopters. The first interpretation implies a kind of normative or cognitive compatibility (compatibility with what people feel or think about a technology), while the second suggests a more practical or operational compatibility (compatibility with what people do). In either case, the compatibility of an innovation to the potential adopter is, theoretically, positively related to adoption and implementation of the innovation. Both of these definitions of compatibility are used in the innovation characteristics literature, though it is sometimes difficult to differentiate between the two.

Perhaps because the definition of compatibility is so broad, compatibility was the most frequently cited characteristic that was studied or mentioned in forty (40) references.

Table III provides a profile of the compatibility studies. The compatibility profile is very similar to the profile of innovation characteristic studies in general (Table I). For this reason, we would like to highlight and explain only two aspects of the compatibility profile: 1) the measurement of compatibility, and 2) the binomial probability of the findings.

A majority of the compatibility studies did not actually measure compatibility in any direct way, but simply inferred that the innovation was compatible to the potential user group. An example of inferring operational or practical compatibility is provided by Brandner (1959) who inferred that the farming innovation hybrid sorghum was most compatible to those farmers who had previously adopted hybrid corn. Duchesneau, Cohn, and Dutton (1980) also inferred the practical compatibility of an innovation by operationally defining an innovation as compatible (actually "suitable") to the adopting firm if the firm possessed certain physical characteristics (e.g., a high percentage of product output of a specific kind) judged to be optimal for application of the innovation. The reliability of any such inferences is also open to question. Again, these studies inferred compatibility; compatibility was not measured

[1] In fact, one of the neglected areas of research in this area is analysis of the interdependence of perceived attributes. Only three of studies reviewed presented intercorrelation tables relevant to this issue, and taken together the data are uninformative.

TABLE III
A METHODOLOGICAL PROFILE OF STUDIES OF COMPATIBILITY

DESIGN ATTRIBUTE	ACTUAL STUDIES				
1) Predictive vs. Retrospective Approach	Predicted Adoption or Implementation		Explained Adoption or Implementation in a Post Hoc Fashion		NA
	5% (2)		90% (37)		5% (2)
2) Dependent Variables	Adoption		Adoption And Implementation		
	93% (38)		7% (3)		
3) Design Methodology	Survey	Secondary Data Analysis	Experiment	Case Study	Theory
	63% (26)	20% (8)	0% (0)	12% (5)	5% (2)
4) Measure of Characteristics	Rated by Decision Makers	Rated by Expert Judges	Cost and Profit	Inferred	NA
	20% (8)	7% (3)	5% (2)	63% (26)	5% (2)
5) Number of Characteristics Considered	One Char-acter-istic	2-5 Char-acter-istics	6-9 Char-acter-istics	10 or more Characteristics	
	44% (18)	34% (14)	15% (6)	7% (3)	
6) Number of Innovations Studied	one innov-ation	2-5 innov-ations	6-9 innov-ations	10 or more innovations	NA
	49% (20)	17% (7)	5% (2)	22% (9)	7% (3)
7) Nature of Adopting Unit	Organization	Individual		Other	NA
	32% (13)	59% (24)		7% (3)	2% (1)
8) Findings (Binomial Probability of Their Direction)	Total N	Studies With Stat's	Studies With r and chi sq. data	Significance	
	41	49%	32% (13)	.046	

as a *perception* of the potential adopter (or decision-maker) or as a perception of an expert judge.

In some of the compatibility references, the compatibility of an innovation was actually rated by innovation decision-makers. For example, Ettlie and Vellenga (1979) had respondents rate each innovation on a one to nine point compatibility scale (where "one" indicated that the innovation was incompatible, while "nine" indicated that the innovation was very compatible). Similarly, Fliegel and Kivlin (1966) had respondents rate operational compatibility, defined by them as "how much different the innovation is from older ways of doing the job," on a four point scale.

Other compatibility studies relied on expert judges' ratings of the compatibility of the innovation. Fliegel and Kivlin (1962), for example, used a panel of twenty judges "who lived in the study area and were thoroughly familiar with its agriculture" to rate the innovation characteristics. The remaining studies fell into one of the other measurement categories.

It should be noted that the inferring of the compatibility characteristic creates special interpretation problems. It is too easy to identify a large number of characteristics of adopters (not innovation characteristics *per se*) and search for those few which significantly differentiate adopters from nonadopters. All too often, these adopter characteristics are then spuriously cited as indicative of the innovation compatibility-innovation adoption relationship. For example, if adopters tend to be older than nonadopters, then the innovation is said to be compatible with "maturity."

Findings: Twenty of the forty compatibility references presented statistical results that were meaningful for our purposes. Of the twenty studies, thirteen reported first-order correlations, rhos, or chi squares between compatibility and adoption from which the direction of the relationship could be discerned. Ten of the thirteen studies found a positive, though not always statistically significant, relationship between the compatibility of an innovation and its adoption. Using our data aggregation procedures, this finding is significant ($p = 0.046$).

While this finding is statistically significant, the strength of the conclusion that the compatibility of an innovation is positively related to its adoption is limited by the fact that some of the studies measured practical compatibility, some value compatibility, and some a combination of the two. Thus the studies in a strict sense should not be lumped together as examples of a single characteristic. Further, the findings do not permit any comparison of the relative predictability of value compatibility and practical compatibility, nor do they permit calculation of the relationship (or intercorrelation) of the two.

Relative Advantage

The relative advantage of an innovation "is the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers and Shoemaker, 1971, p. 138). But, "being better" is such a general notion that the measurement of relative advantage presents several problems. According to Rogers and Shoemaker (1971, p. 138), relative advantage may be "expressed in economic profitability, but the relative advantage dimension may [also] be measured in other ways." If relative advantage is measured in terms of profitability, or social benefits, or time saved, or hazards removed, why bother to refer to relative advantage at all? There seems to be no good reason. Relative advantage is perhaps too broad and amorphous a characteristic to be of much use. Typically, it is the garbage pail characteristic in innovation characteristic studies into which any of a number of innovation characteristics are dumped. Under these circumstances, relative advantage studies lack conceptual strength, reliability, and prescriptive power. (One can hardly help an innovation developer by suggesting that he or she maximize the innovation's "relative advantage.")

For these reasons, we have attempted to exclude from the present discussion those studies cited by previous reviewers as relative advantage studies that clearly refer to another, more specific characteristic. (Instead, such studies are reviewed under the heading of the characteristic actually measured, e.g., the profitability of the innovation.) Nonetheless, relative advantage is still, with 29 reference cities, a frequently considered characteristic.

The profile of the relative advantage studies is presented in Table IV. Again, the relative advantage profile tends to parallel that of the innovation characteristic studies in general. Particularly noteworthy are the problems associated with the measurement of an innovation's relative advantage. The majority of the relative advantage studies inferred the relative advantage of the innovation. Martino, Chen, and Lenz (1978), for example, did their own evaluation of the relative advantage

TABLE IV
A METHODOLOGICAL PROFILE OF STUDIES OF RELATIVE ADVANTAGE

DESIGN ATTRIBUTE	ACTUAL STUDIES				
1) Predictive vs. Retrospective Approach	Predicted Adoption or Implementation	Explained Adoption or Implementation in a Post Hoc Fashion	NA		
	2.7% (1)	90.7% (28)	6.7% (5)		
2) Dependent Variables	Adoption	Adoption And Implementation			
	93.3% (27)	6.7% (2)			
3) Design Methodology	Survey	Secondary Data Analysis	Experiment	Case Study	Theory
	59% (17)	21% (6)	0% (0)	17% (5)	3% (1)
4) Measure of Characteristics	Rated by Decision Makers	Rated by Expert Judges	Cost and Profit	Inferred	NA
	24% (7)	14% (4)	7% (2)	52% (15)	3.5% (1)
5) Number of Characteristics Considered	One Characteristic	2-5 Characteristics	6-9 Characteristics	10 or more Characteristics	
	17% (5)	53% (17)	17% (5)	7% (2)	
6) Number of Innovations Studied	One innovation	2-5 innovations	6-9 innovations	10 or more innovations	NA
	34.5% (10)	21% (6)	3% (1)	34.5% (10)	7% (2)
7) Nature of Adopting Unit	Organization	Individual	Other	NA	
	38% (11)	52% (15)	10% (3)	0% (0)	
8) Findings (Binomial Probability of Their Direction)	Total N	Studies With Stat's	Studies With r and chi sq. data	Significance	Expected Direction
	29	38% (11)	17% (5)	.031	Yes

TABLE V
A METHODOLOGICAL PROFILE OF STUDIES OF COMPLEXITY

DESIGN ATTRIBUTE	ACTUAL STUDIES				
1) Predictive vs. Retrospective Approach	Predicted Adoption or Implementation	Explained Adoption or Implementation in a Post Hoc Fashion	NA		
	5% (1)	90% (19)	5% (1)		
2) Dependent Variables	Adoption	Adoption And Implementation			
	95% (20)	5% (1)			
3) Design Methodology	Survey	Secondary Data Analysis	Experiment	Case Study	Theory
	81% (17)	9.5% (2)	0% (0)	5% (1)	5% (1)
4) Measure of Characteristics	Rated by Decision Makers	Rated by Expert Judges	Cost and Profit	Inferred	NA
	33% (7)	14% (3)	0% (0)	48% (10)	5% (1)
5) Number of Characteristics Considered	One Characteristic	2-5 Characteristics	6-9 Characteristics	10 or more Characteristics	
	5% (1)	34% (7)	38% (8)	24% (5)	
6) Number of Innovations Studied	one innovation	2-5 innovations	6-9 innovations	10 or more innovations	na
	19% (4)	19% (4)	5% (1)	48% (10)	10% (2)
7) Nature of Adopting Unit	Organization	Individual	Other	NA	
	38% (8)	62% (13)	0% (0)	0% (0)	
8) Findings (Binomial Probability of Their Direction)	Total N	Studies With Stat's	Studies With r and chi sq. data	Significance	
	21	62% (13)	33% (7)	.062	

of the industrial innovations they examined ("relative to whatever the innovation replaced, and the relative advantage included profitability, productivity, reduced labor requirements, or any other measure of advantage which seemed pertinent," p. 10), rather than seeking the ratings of potential adopters or expert judges. Their definition of relative advantage illustrates the hodge-podge of specific characteristics actually subsumed in the relative advantage category.

In another example of inferring relative advantage, a historical case study, originally cited by Rogers and Shoemaker as a relative advantage study, Miller (1957) suggested that the smallpox inoculation was accepted in the 18th century because its effectiveness (or relative advantage) was obvious "at least among the segment of public opinion that was capable of being convinced by rational arguments based upon mathematical and experimental demonstration" (p. 275).

In some of the relative advantage studies, the relative advantage of an innovation was more adequately measured as adopters' or judges' ratings of the innovation(s). For example, Hayward, Allen and, Masterson (1976) had their respondents rate flour milling innovations according to a number of characteristics including "mechanical advantage." In Ettlie and Vellenga's study (1979) of transportation innovations, potential adopters rate the innovations' relative advantage ("over previous ideas") on a nine-point scale. In Coe and Barnhill (1967), users of a new hospital medications system rated the system's effectiveness on a number of criteria specific to the system such as the ease with which medications were distributed to patients.

Findings: Of the 29 studies of relative advantage, only eleven reported statistical results directly relevant to the relationship of the relative advantage of an innovation to its adoption. Five reported correlations or chi squares that could be used in a binomial test of significance. All five studies found relative advantage to be positively related to adoption. The binomial probability associated with these findings, under the null hypothesis assumption of a 50-50 split, is significant ($p = 0.031$).

Complexity

The complexity of an innovation is "the degree to which an innovation is perceived as relatively difficult to understand and use (Rogers and Shoemaker, 1971, p. 154). Complexity is assumed to be negatively related to innovation adoption and implementation. Complexity was cited in 21 of the references reviewed.

Table V outlines the profile of complexity studies. In general, the modal complexity is somewhat more sophisticated than the modal innovation characteristic study. Complexity studies used more sophisticated designs (especially surveys), used better measures of the innovation characteristic(s) (es-

TABLE VI
A METHODOLOGICAL PROFILE OF STUDIES OF COST

DESIGN ATTRIBUTE	ACTUAL STUDIES				
1) Predictive vs. Retrospective Approach	Predicted Adoption or Implementation	Explained Adoption or Implementation in a Post Hoc Fashion	NA		
	0% (0)	90% (18)	10% (2)		
2) Dependent Variables	Adoption	Adoption And Implementation			
	95% (19)	5% (1)			
3) Design Methodology	Survey	Secondary Data Analysis	Experiment	Case Study	Theory
	60% (12)	20% (4)	0% (0)	10% (2)	10% (2)
4) Measure of Characteristics	Rated by Decision Makers	Rated by Expert Judges	Cost and Profit	Inferred	NA
	35% (7)	5% (1)	15% (3)	35% (7)	10% (2)
5) Number of Characteristics Considered	One Characteristic	2-5 Characteristics	6-9 Characteristics	10 or more Characteristics	
	10% (2)	35% (7)	30% (6)	25% (5)	
6) Number of Innovations Studied	One innovation	2-5 innovations	6-9 innovations	10 or more innovations	NA
	20% (4)	15% (3)	0% (0)	55% (11)	10% (2)
7) Nature of Adopting Unit	Organization	Individual	Other	NA	
	45% (9)	50% (10)	0% (0)	5% (1)	
8) Findings (Binomial Probability of Their Direction)	Total N	Studies With Stat's	Studies With r and chi sq. data	Significance	
	20	55% (11)	25% (5)	.50	

TABLE VII
A METHODOLOGICAL PROFILE OF STUDIES OF COMMUNICABILITY

DESIGN ATTRIBUTE	ACTUAL STUDIES				
1) Predictive vs. Retrospective Approach	Predicted Adoption or Implementation	Explained Adoption or Implementation in a Post Hoc Fashion	NA		
	0% (0)	100% (13)	0% (0)		
2) Dependent Variables	Adoption	Adoption And Implementation			
	100% (13)	0% (0)			
3) Design Methodology	Survey	Secondary Data Analysis	Experiment	Case Study	Theory
	61% (8)	15% (2)	8% (1)	15% (2)	0% (0)
4) Measure of Characteristics	Rated by Decision Makers	Rated by Expert Judges	Cost and Profit	Inferred	NA
	0% (0)	15 (2)	0% (0)	85% (11)	0% (0)
5) Number of Characteristics Considered	One Characteristic	2-5 Characteristics	6-9 Characteristics	10 or more Characteristics	
	31% (4)	53% (7)	15% (2)	0% (0)	
6) Number of Innovations Studied	One innovation	2-5 innovations	6-9 innovations	10 or more innovations	NA
	46% (6)	23% (3)	0% (0)	31% (4)	0% (0)
7) Nature of Adopting Unit	Organization	Individual	Other	NA	
	23% (3)	77% (10)	0% (0)	0% (0)	
8) Findings (Binomial Probability of Their Direction)	Total N	Studies With Stat's	Studies With r and chi sq. data	Significance	
	13	23% (3)	0% (0)	N.A.	

pecially adopters' ratings), and they tended to study more characteristics and more innovations at a single time.

Findings: Thirteen of the twenty-one complexity studies contained meaningful statistical analyses for our purposes. In seven of the thirteen studies, first-order correlations or chi squares were available so that the relationship of complexity alone to adoption could be examined. All but one of the seven studies found a negative relationship between the complexity of an innovation and its adoption. The binomial probability of this six to one ratio approaches acceptable levels of statistical significance ($p = 0.062$).

Cost

The cost of an innovation is assumed to be negatively related to the adoption and implementation of the innovation; the less expensive the innovation, the more likely it will be quickly adopted and implemented. Twenty studies examined the initial cost of an innovation as a factor influencing adoption and implementation of innovations.

The profile of cost studies is presented in Table VI. Because cost is a relatively easy characteristic to measure, the cost studies typically used better measurement than the modal innovation characteristic study. Cost studies also tended to consider more characteristics and more innovations than the modal innovation characteristic study.

Findings: Ten of the fifteen cost studies reported statistical findings about the relationship of the cost of an innovation to its adoption. Five of these ten studies reported correlational data. Three found the cost of an innovation to be positively related to its adoption, and two found cost to be negatively correlated with adoption. This is nonsignificant ($p = 0.50$).

Communicability

The communicability of an innovation is "the degree to which aspects of an innovation may be conveyed to others" (Rothman, 1974, p. 441). The communicability of an innovation is presumed to be positively related to the adoption and implementation of the innovation. This characteristic was measured or discussed in thirteen of the references reviewed. (The notion of communicability is very similar to and obviously related to that of observability. The latter refers to the extent to which the results of an innovation are visible to others. Observability is discussed in a section devoted to it alone, below.)

The profile of the communicability studies appears in Table VII. In general, the communicability studies were even less methodologically rigorous than the typical innovation characteristics study. The vast majority (85 percent) of the communicability studies inferred the communicability of the innovation. For example, Danda and Danda (1968) simply reported that "... the farmers accepted the innovation more readily when the results of adoption were visible that when they were obscure ... Villagers' lack of response toward improved cultural practices also confirms that they are skeptical to accept an innovation whose result is not visible or understandable to them" (pp. 201–202). In none of the communicability studies were the innovation characteristics actually rated by the innovation adopters.

Findings: While communicability was discussed in thirteen references, only three of those references reported statistical findings directly relevant to the communicability–adoption relationship. None of these studies permitted direct statistical examination of this relationship using our procedure. (One study provided only mean rating scores, one provided only a summary regression, with only regression and partial correlation coefficients published, and the third was a discriminant analysis with no first-order correlations reported.)

TABLE VIII
A METHODOLOGICAL PROFILE OF STUDIES OF DIVISIBILITY

DESIGN ATTRIBUTE	ACTUAL STUDIES				
1) Predictive vs. Retrospective Approach	Predicted Adoption or Implementation		Explained Adoption or Implementation in a Post Hoc Fashion		NA
	0% (0)		90% (9)		10% (1)
2) Dependent Variables	Adoption		Adoption And Implementation		
	100% (10)		0% (0)		
3) Design Methodology	Survey	Secondary Data Analysis	Experiment	Case Study	Theory
	80% (8)	10% (1)	0% (0)	0% (0)	10% (1)
4) Measure of Characteristics	Rated by Decision Makers	Rated by Expert Judges	Cost and Profit	Inferred	NA
	40% (4)	30% (3)	0% (0)	20% (2)	10% (1)
5) Number of Characteristics Considered	One Characteristic	2–5 Characteristics	6–9 Characteristics	10 or more Characteristics	
	0% (0)	40% (4)	20% (2)	40% (4)	
6) Number of Innovations Studied	One innovation	2–5 innovations	6–9 innovations	10 or more innovations	NA
	0% (0)	10% (1)	10% (1)	60% (6)	10% (1)
7) Nature of Adopting Unit	Organization	Individual		Other	NA
	20% (2)	80% (80)		0% (0)	0% (0)
8) Findings (Binomial Probability of Their Direction)	Total N	Studies With Stat's	Studies With r and chi sq. date	Significance	
	10	60% (6)	50% (5)	.50	

Divisibility

The divisibility of an innovation is the "extent to which an innovation can be tried on a small scale prior to adoption" (Fliegel, Kivlin, and Sekhon, 1968, p. 446). (Hybrid corn and sorghum, for example, are frequently described as highly divisible innovations.) The divisibility of an innovation is closely related to its trialability, or "the degree to which an innovation may be experimented with on a limited basis" (Rogers and Shoemaker, 1971, p. 155). A highly divisible innovation is usually highly "trialable." However, not all "trialable" innovations are divisible; a trialable innovation may simply be a relative small, easily reversable, nonradical innovation. For the purposes of this review, the two characteristics (divisibility and trialability) are discussed separately. Divisibility was cited in ten of the innovation characteristics references.

Table VIII provides the profile of these studies. In general, the divisibility studies tended to use better designs and measures than the typical innovation characteristics study. The divisibility studies also tended to study more characteristics and more innovations than the modal innovation characteristics study.

Findings: Six of the ten studies reported the results of statistical tests of the divisibility–adoption relationship. Five of these six offered direct statistical evidence of the relationship of an innovation's divisibility to its adoption. Three of these found divisibility to be positively related to adoption while the other two showed a negative relationship. No conclusion can be made on the basis of these five findings.

Profitability

The profitability of an innovation is the level of profit to be gained from adoption of the innovation. This characteristic may not be appropriate for all innovations, such as consumer products (where the "adopter" is the consumer), or some social innovations. Ten studies measured the profitability of an innovation as a factor in its adoption.

The profitability studies are reviewed in Table IX. The Table shows that the profitability studies were somewhat more sophisticated than the typical innovation characteristic study. A large number of the studies were able to use secondary (or published) data of the impact of expected or actual profit on innovation adoption. For example, Ray (1969) based his analysis of the diffusion of the oxygen steel plant (its productivity, relative advantage, etc.) on various previous studies of oxygen steel plants. Similarly, Massy (1960) used published data about monochrome television receivers in his analysis of factors influencing the adoption of new television receivers.

Findings: Eight of the ten profitability studies included statistical tests of the relationship of an innovation's profitability to its adoption. Four of these studies provided first-order correlation data. Three found profitability to be negatively related to aboption. This is surprising given the strong theoretical argument for a positive relationship between an innovation's profitability and its adoption. The finding is obviously nonsignificant, and in fact the number of observations is too low to even permit a defensible statistical test.

Social Approval

Social approval refers to status gained in one's reference group, "a nonfinancial aspect of reward" (Fliegel, Kivlin, and Sekhon, 1968, p. 445), as a function of adopting a particular innovation. This characteristic of an innovation clearly represents the concept of the innovation characteristic as a product of the interaction of the innovation and the adopting unit (though many other innovation characteristics are also well represented in this manner.) Eight studies cited this characteristic.

TABLE IX
A METHODOLOGICAL PROFILE OF STUDIES OF PROFITABILITY

DESIGN ATTRIBUTE	ACTUAL STUDIES				
1) Predictive vs. Retrospective Approach	Predicted Adoption or Implementation	Explained Adoption or Implementation in a Post Hoc Fashion	NA		
	0% (0)	100% (10)	0% (0)		
2) Dependent Variables	Adoption	Adoption And Implementation			
	100% (10)	0% (0)			
3) Design Methodology	Survey	Secondary Data Analysis	Experiment	Case Study	Theory
	50% (5)	50% (5)	0% (0)	0% (0)	0% (0)
4) Measure of Characteristics	Rated by Decision Makers	Rated by Expert Judges	Cost and Profit	Inferred	NA
	40% (4)	0% (0)	50% (5)	10% (0)	0% (0)
5) Number of Characteristics Considered	One Char-acter-istic	2-5 Char-acter-istics	6-9 Char-acter-istics	10 or more Characteristics	
	30% (3)	40% (4)	0% (0)	30% (3)	
6) Number of Innovations Studied	One innov-ation	2-5 innov-ations	6-9 innov-ations	10 or more innovations	NA
	20% (2)	0% (0)	0% (0)	80% (8)	0% (0)
7) Nature of Adopting Unit	Organization	Individual	Other	NA	
	40% (4)	60% (6)	0% (0)	0% (0)	
8) Findings (Binomial Probability of Their Direction)	Total N	Studies With Stat's	Studies With r and chi sq. data	Significance	
	10	80% (8)	40% (4)	N.A.	

TABLE X
A METHODOLOGICAL PROFILE OF STUDIES OF SOCIAL APPROVAL

DESIGN ATTRIBUTE	ACTUAL STUDIES				
1) Predictive vs. Retrospective Approach	Predicted Adoption or Implementation	Explained Adoption or Implementation in a Post Hoc Fashion	NA		
	0% (0)	87.5% (7)	12.5% (1)		
2) Dependent Variables	Adoption	Adoption And Implementation			
	100% (8)	0% (0)			
3) Design Methodology	Survey	Secondary Data Analysis	Experiment	Case Study	Theory
	87.5% (7)	0% (0)	0% (0)	0% (0)	12.5% (1)
4) Measure of Characteristics	Rated by Decision Makers	Rated by Expert Judges	Cost and Profit	Inferred	NA
	75% (6)	12.5% (1)	0% (0)	12.5% (1)	0% (0)
5) Number of Characteristics Considered	One Char-acter-istic	2-5 Char-acter-istics	6-9 Char-acter-istics	10 or more Characteristics	
	0% (0)	50% (4)	12.5% (1)	37.5% (3)	
6) Number of Innovations Studied	One innov-ation	2-5 innov-ations	6-9 innov-ations	10 or more innovations	NA
	12.5% (1)	25% (2)	0% (0)	62.5% (5)	0% (0)
7) Nature of Adopting Unit	Organization	Individual	Other	NA	
	25% (2)	75% (6)	0% (0)	0% (0)	
8) Findings (Binomial Probability of Their Direction)	Total N	Studies With Stat's	Studies With r and chi sq. data	Signi-ficance	
	8	50% (4)	37.5% (3)	N.A.	

Table X provides an overview of the social approval studies. In general, they too are somewhat better than the modal innovation characteristics study; they tended to use better designs more frequently and they measured more characteristics and studied more innovations.

Findings: Four of the eight references for social approval contained statistical information for our purposes. Three of these four provided first-order correlation data. Two of the studies reported a negative, nonsignificant relationship, and the third a significantly positive relationship. No statistical conclusions are possible here.

Trialability

Trialability is "the degree to which an innovation may be experimented with on a limited basis" (Rogers and Shoemaker, 1971, p. 155). Theoretically, innovations "that can be tried on the installment plan" (Rogers and Shoemaker, 1971, p. 155) will be adopted and implemented more often and more quickly than less trialable innovations. Eight innovation characteristics references cited trialability. Table XI reviews the trialability studies.

Findings: Of the eight studies mentioning trialability, five provided statistical results. These five cannot be easily summarized in anyway, however, as only one study reported the first-order correlation, two performed discriminant analyses alone, one provided only mean characteristic rating scores, and the last reported chi square results but no actual numbers from which to infer directionality of the relationship.

Observability

Observability is "the degree to which the results of an innovation are visible to others" (Rogers and Shoemaker, 1971, p. 155). The more visible the results of an innovation, the more likely the innovation will be quickly adopted and implemented. Observability is cited in seven innovation characteristics references.

Table XII presents the profile of observability studies. While the majority of the studies had adopters rate the innovations, a large number still relied on inferring the observability of an innovation. For example, Alers-Montalvo (1953) simply states that two of the three farming innovations he studied were accepted because, among other reasons, "villagers were provided with objective proof of their efficiency" (p. 177). One of the difficulties concerning the dimension of observability is its obvious potential for confounding with other perceived attributes. It is unclear whether observability *per se* is being assessed, or observability of cost, compatibility, effects, etc.

TABLE XI
A METHODOLOGICAL PROFILE OF STUDIES OF TRIALABILITY

DESIGN ATTRIBUTE	ACTUAL STUDIES				
1) Predictive vs. Retrospective Approach	Predicted Adoption or Implementation	Explained Adoption or Implementation in a Post Hoc Fashion	NA		
	12.5% (1)	75% (6)	12.5% (1)		
2) Dependent Variables	Adoption	Adoption And Implementation			
	87.5% (7)	12.5% (1)			
3) Design Methodology	Survey	Secondary Data Analysis	Experiment	Case Study	Theory
	75% (6)	12.5% (1)	0% (0)	0% (0)	12.5% (1)
4) Measure of Characteristics	Rated by Decision Makers	Rated by Expert Judges	Cost and Profit	Inferred	NA
	50% (4)	0% (0)	0% (0)	50% (4)	0% (0)
5) Number of Characteristics Considered	One Characteristic	2-5 Characteristics	6-9 Characteristics	10 or more Characteristics	
	0% (0)	37.5% (3)	50% (4)	12.5% (1)	
6) Number of Innovations Studied	One innovation	2-5 innovations	6-9 innovations	10 or more innovations	NA
	12.5% (1)	50% (4)	0% (0)	2.5% (2)	12.5% (1)
7) Nature of Adopting Unit	Organization	Individual	Other	NA	
	62.5% (5)	37.5% (3)	0% (0)	0% (0)	
8) Findings (Binomial Probability of Their Direction)	Total N	Studies With Stat's	Studies With r and chi sq. data	Significance	Expected Direction
	8	62.5% (5)	12.5% (1)	N. A.	

TABLE XII
A METHODOLOGICAL PROFILE OF STUDIES OF OBSERVABILITY

DESIGN ATTRIBUTE	ACTUAL STUDIES				
1) Predictive vs. Retrospective Approach	Predicted Adoption or Implementation	Explained Adoption or Implementation in a Post Hoc Fashion	NA		
	14% (1)	86% (6)	0% (0)		
2) Dependent Variables	Adoption	Adoption And Implementation			
	86% (6)	14% (1)			
3) Design Methodology	Survey	Secondary Data Analysis	Experiment	Case Study	Theory
	71% (5)	14% (1)	0% (0)	14% (1)	0% (0)
4) Measure of Characteristics	Rated by Decision Makers	Rated by Expert Judges	Cost and Profit	Inferred	NA
	57% (4)	0% (0)	0% (0)	43% (3)	0% (0)
5) Number of Characteristics Considered	One Characteristic	2-5 Characteristics	6-9 Characteristics	10 or more Characteristics	
	0% (0)	43% (3)	57% (4)	0% (0)	
6) Number of Innovations Studied	One innovation	2-5 innovations	6-9 innovations	10 or more innovations	NA
	14% (1)	43% (3)	0% (0)	29% (2)	14% (1)
7) Nature of Adopting Unit	Organization	Individual	Other	NA	
	57% (4)	43% (3)	0% (0)	0% (0)	
8) Findings (Binomial Probability of Their Direction)	Total N	Studies With Stat's	Studies With r and chi sq. data	Significance	Expected Direction
	7	57% (4)	29% (2)	N. A.	

Findings: Four of the seven observability studies reported statistical results relevant to our needs. Of these four, only two provided any direct correlational measure of the observability–adoption relationship.

DISCUSSION

On the basis of our review and meta-analysis of innovation characteristics research, it is clear: 1) that the study of innovation characteristics is typified by poor conceptualization and research methodology; 2) that in spite of these weaknesses, the relationship between certain innovation characteristics and adoption-implementation shows some consistency in directionality; and 3) that given these two conclusions, more (and better) research is needed to verify and elaborate the relationship of innovation attributes to adoption and implementation of innovations. Several recommendations for needed research are given below.

General Lack of Appropriate Method

In order to provide a conceptual and methodological framework for evaluating the research studies, we developed seven criteria for the hypothetically "ideal" innovation characteristics study:

1) The ideal study should be a predictive (not retrospective) study. Assessment of an innovation attribute should generally be obtained prior to, or concurrently with, a decision to adopt the innovation, and not after the fact. Perceptions of the attribute subsequent to the adoption/rejection decision may be affected by the perceiver's knowledge of that decision.
2) The ideal study should measure adoption *and* implementation as dependent variables. This is necessary for the research to fully account for the adoption process, through utilization or routinization, not just the adoption decision.
3) The ideal study should utilize an appropriate research design, i.e., experimental, survey, or secondary data analysis (analysis of data collected by another person and/or for a different purpose). Theoretical pieces and single site qualitative case studies cannot contribute significantly to the advancement of the empirical knowledge base at this time.
4) The ideal study should utilize replicable measures of innovation attributes, and data gathered from participants in the process. Simply inferring the level of certain innovation characteristics is not adequate.
5) The ideal study should study more than one innovation. Single innovation studies are not sufficiently robust to permit generalization to a population of innovations.

6) The ideal study must consider more than one innovation attribute so as to fully describe the innovation and also to allow for comparisons of the attributes.
7) The ideal study should focus on innovations in organizational (not individual) settings so that the studies will have implications for the organizational (and interorganizational) innovation process of most public policy concern.

In general, the innovation characteristic studies fail to meet the seven guidelines we have proposed as a yardstick or paradigm for this area.

Prediction: Only two (Ostlund, 1974; Tornatzky *et al.*, 1980) of the seventy-five studies we reviewed employed a design in which innovation characteristics were measured or evaluated prior to the adoption decision. But measurement of innovation characteristics prior to adoption is preferable if perceptions of innovation characteristics are not to be confounded by the ultimate adoption or rejection decision.

Adoption and Implementation: Only five of the studies attempted to measure implementation as a dependent variable. Only one study (Tornatzky *et al.*, 1980) measured degree of implementation over a fairly long time period. While the relatively more common use of the delay between adoption and actual implementation as a dependent variable in innovation characteristics studies is an improvement over the simple adoption decision dependent variable, only measures of degree of implementation begin to capture the variability of post-adoption behavior.

Design: The majority of innovation characteristic studies employed defensible designs. Surveys, secondary data analyses, and experiments or quasi-experiments are all commonly used. However, these designs were all too often rendered useless by inappropriate and unsystematic measures of the independent variable, the innovation characteristic(s).

Measures: Unfortunately, the majority of the reviewed studies *inferred* the existence of the innovation characteristics and/or their influence on adoption decisions, rather than systematically measuring perceived characteristics. Replicable measures of innovation characteristics are essential for meaningful, generalizable results. The innovation characteristic rating scales used, for example, by Fliegel and Kivlin (1962, 1966) and Ettlie and Vellenga (1979) provide a starting point for the measurement of perceived innovation characteristics. (In these measures, each innovation is rated by the potential adopters on a four, or nine, point scale for each attribute, e.g., from low to high complexity.) It should also be noted that measurement reliability would be enhanced by employing multi-item scales for each characteristic as opposed to single item measures.

Number of Characteristics Studied: Innovation characteristic studies have been further undermined by the study of only one innovation characteristic in nearly one half of the studies reviewed. These studies do not allow the comparison of several innovation characteristics within the same study. There is thus a need for the examination of several innovation characteristics within a single study.

Number of Innovations Studied: The innovation characteristics studies typically addressed only a small number of innovations in each study. In more than one half of the studies, only one innovation was examined. These single innovation studies do not permit comparison across innovations and, therefore, lack generalizability.

Nature of Adopting Unit: A final criticism of the innovation characteristics literature is that it too often has focused on innovations for individual adopters. Only one-third of the studies considered innovations for organizations. Future studies should emphasize such innovations in order to increase the policy relevance of these studies to issues of organizational productivity.

This review of the innovation characteristic studies on the basis of the seven yardstick features summarizes the problems of the literature and helps to explain both the paucity of research results in the studies and the variability (or instability) of the existing research results. While some of the seven features may be more important than others, we feel that they provide guidelines for future research in this area. Research studies similar to Ettlie and Vellenga's study (1979) which has an appropriate design, replicable measure, and a consideration of several characteristics and several organizational innovations, supplemented by the use of a predictive design and the measurement of degree of implementation (as in Tornatzky *et al.*, 1980), would provide a significant contribution to the field.

Most Promising Meta-Analysis Findings

In addition to reviewing the innovation characteristics literature, we also performed a meta-analysis of the research results describing the direct relationship (or first-order correlation) of innovation attributes to adoption. In our meta-analysis, we evaluated the consistency of the direction of correlational findings without regard for the magnitude or statistical significance of the individual correlations. In essense, this technique simply compares the directions of the actual findings for a particular characteristic to the null hypothesis of a 50-50 split in the direction of the findings, and uses binomial probability to measure the significance of the result. The results of our meta-analysis showed only three of the ten characteristics we reviewed in detail to be consistently related to adoption.

Two of the characteristics, compatibility and relative advantage, were positively related to adoption ($p < 0.05$). Both of these characteristics, however, deserve further conceptualization. Compatibility, for example, has been construed to refer to either value or practical congruence with the adopter's values or practical needs and history. The available research has typically failed to adequately distinguish between the two definitions of compatibility or to test their relationship. Relative advantage is a still more ambiguous term. Researchers too often fail to specify the criteria for judging relative advantage; is an innovation advantageous because it cost less, is less complex, or what? Furthermore, the inherent reasoning is circular: an innovation is said to be better because it is advantageous.

One other characteristic, complexity, was negatively related to adoption at a near-acceptable level of statistical significance ($p = 0.062$). The concept of the complexity of an innovation, on the other hand, lacks—like many innovation characteristics—a certain specificity. Just what makes an innovation become perceived as complex, or more accurately, what makes people perceive it as complex?

Other innovation characteristics may prove significantly related to adoption and/or implementation as new studies of innovation characteristics accumulate. In our meta-analysis, we were often hampered by the small *N* of studies actually reporting first-order correlational data. For example, for seven of the ten characteristics we reviewed, there were five or fewer studies reporting chi square or correlational data relevant to the characteristic–adoption relationship.

Research Needs

The Need for More (and Better) Research: This review of the innovation characteristic literature demonstrates the need for more research in this area. While the Rogers and Shoemaker (1971) review seems to overstate what we know about innovation characteristics, and Downs and Mohr (1976) assert that the study of innovation characteristics is inherently fruitless, our study challenges both of these positions. Because the existing literature is so poor, we certainly do not know all there is to know about innovation characteristics. On the other hand, despite all the methodological weaknesses the relationships that we were able to tease out using meta-analytic techniques suggest that more and better studies could elaborate these findings. This line of research should not be abandoned.

Assuming that additional research could strengthen the magnitude of findings, and make more consistent their directionality, this would be of considerable practical and conceptual importance. As illustrated by the Downs and Mohr (1976) argument our understanding of the innovation process is fragile. Much of the field has fallen back on technology-specific, industry-specific, or organization-specific explanations of innovation. This has tended both to preclude common policy concerning innovation and to fragment the research literature. If it could be demonstrated that a finite number of perceived characteristics seem to be consistently related to innovation adoption and implementation across settings and technologies this would serve to focus both policy and research.

We can illustrate the utility of future research in this area if we consider perceived characteristics as akin to proxy variables for other underlying processes. For example, two variables which showed a modicum of directional consistency in our study were perceived compatibility and complexity. It also should be noted that other innovation research, from an organizational theoretical perspective, has identified the concept of task uncertainty as particularly important in innovation. In turn, other research (e.g., Tornatzky *et al.*, 1980) has suggested that participative, decentralized organizational structure may be one way of coping with the uncertainty and nonuniformity of innovation. One could argue—and test empirically—that perceived innovation characteristics such as compatibility and complexity are merely indices of the degree and type of "uncertainty-arousing" potential that an innovation has. Thus both the rather abstract innovation characteristics that have been studied could be unraveled, and some suggestions for more integrative research developed. Much of this is of course contingent on getting a better empirical fix on perceived innovation characteristics.

Our seven criteria paradigm for the ideal innovation characteristic study provides our basic suggestions for future research although we do not consider it as methodological gospel for innovation research. It has proved helpful to us in assessing the strengths and weaknesses of the literature reviewed. Rather than reiterating these seven suggestions here, we will focus on other unresolved research issues that merit further attention and work.

The Need to Reduce the Number of Attributes: The innovation characteristics field seems to suffer from the seemingly constant discovery and/or re-naming of innovation characteristics. We came across more than thirty innovation characteristics in the course of our review. While the identification of "new" innovation characteristics (e.g., risk, and impact on work relationships) may be useful, there is a real need to determine the empirical independence of these characteristics and to eliminate redundant characteristics.

Factor analysis and other multivariate techniques would be helpful in such an exercise. It seems intuitively obvious that the literally dozens of innovation characteristics in the literature are in fact sampling interdependent measurement domains, and that data reduction techniques will yield a smaller, empirically defensible array. Even the simple calculation by researchers of innovation characteristic intercorrelation matrices would be a useful first step to identify related (or redundant) characteristics.

The Need to Study Other Independent Variables in Addition to Innovation Characteristics: Studies of innovation attributes might profitability consider other independent variables in addition to innovation characteristics. Ettlie and Vellenga (1979), for example, studied measures of the adopting organizations as well as innovation characteristics. Thus they were able to examine the interaction of innovation characteristics and organizational features in predicting the time lag between stages of the adoption process. Additional studies of innovation attributes could help further define the fit between organization and technology. The study of innovation characteristics need not be the be-all, end-all of studies of the innovation process. Rather, measures of characteristics of innovations could be profitably embedded within more far-reaching studies of the innovation process. It should be noted that the Tornatzky *et al.* (1980) study was not primarily a study of innovation characteristics, but of the relationship between participative decision-making and innovation adoption-implementation.

The Need to Improve Measurement and Conceptualization of Innovation Characteristics: Throughout this paper we have emphasized the value of measuring innovation characteristics by obtaining the actual perceptions of potential adopters. We have also emphasized the importance of considering organizational innovations. There is a potential contradiction here: Who should rate the innovation characteristics if the potential adopter is not an individual, but an organization or unit within an organization? Our best answer to this question is that several ratings of the innovation, from several echelons within an organization, should be obtained. Ratings of the same innovation(s) by different members of the organization could be compared, and it is an empirical question which person's score, or aggregation of persons, would have the best predictive utility. Hage's (1980) concept of the "dominant coalition" could guide the selection of respondents. It is quite possible, for example, that the ratings of the executive management may correlate most highly with adoption, while those of the employees most directly affected by the innovation would correlate most highly with implementation. However, it should be noted that Ettlie and Vellenga (1979) found considerable agreement among respondents on the ratings of attributes.

Operationalizing Subjective Perceptions: Another issue related to innovation attributes is the relationship of potential adopters' perceptions to "objective" or operational aspects of the technology itself. For example, when is an innovation described as complex? Does "complexity" refer to the technical knowledge needed to use an innovation? To the impact of the innovation on existing working relations? To the innovation's physical appearance? A useful approach to answering these questions might involve examining the statistical relationship between perceptual and objective descriptions of innovations. (A good example of the general issue of perceived versus "objective" measures is that of environment uncertainty, as discussed by Downey *et al.* [1975].) If innovation attributes (e.g., cost) could be normalized by considering their magnitude relative to other variables (e.g., resources) across other adopting units, then the distinction between subjective and objective attributes would be less distinct. This, incidentally, would make the argument against doing retrospective studies less crucial.

Clearly, this is a future concern and one that represents the study of innovation attributes coming full circle. Once a body of literature exists on the relationship of perceptual measures of attributes to adoption and implementation, the examination of the relationship of perceptual and more objective measures will be useful. For example, there is general agreement about the differences between the generic classes of product versus process innovation. What is unclear is how these generic classes fold into the more perceptual attributes of complexity, compatability, etc.

The Need to Develop Viable Measures of Implementation: Measures of degree of implementation are likely to be idiosyncratic to the innovation(s) in question. For example, it may be difficult to devise comparable measures of implementation for an education innovation, a technological innovation, and an agricultural innovation. Subsequent research and conceptualization will be needed to maximize the generalizability of implementation measures. Our tentative suggestions for meaningful measures of implementation are 1) that degree of utilization, as a proportion of the maximum, be used to measure the implementation of unitary innovations; and 2) that implementation of key features or aspects of the innovation be used to be used to measure the implementation of nonunitary or more complex (socio-technical) innovations. In any case, it is critical that implementation be measured longitudinally using a repeated measures approach, so as to capture the unfolding process over time. Implementation periods that run into *years* are not uncommon (Ettlie and Rubenstein, 1980). Multiple measures of implementation (e.g., naturalistic or unobtrusive measures and perceptual measures) are, of course, also desirable.

A major conceptual issue also related to the study of innovation characteristics and implementation is the development of hypotheses for the innovation characteristic-implementation relationship. While the expected directions for the innovation characteristics-adoption relationship are well-established in the theoretical literature, it remains a conceptual (and empirical) issue whether the same relationships will hold for implementation. For instance, it makes sense that, other things being equal, the more costly an innovation is, the less likely it is to be adopted. Once adopted, however, the costlier innovation may in fact be more likely to be fully implemented; having already invested a large sum in the innovation, the adopter may be highly motivated to fully use the innovation. This, of course, reinforces our previous comments about the necessity to use adoption and implementation as dependent variables.

The summative judgment and recommendation that we come away from our review of innovation characteristics research is that this is a potentially fruitful research area that needs further and, more importantly, better work. We do not see it as an isolated minor area in a larger body of research, but as a potential key to integrate that larger body of research. As in all reviews of this sort we have doubtless missed some references and perhaps others would code some of the studies in slightly different ways. However, our feeling is that the profile that we have drawn of this research literature is substantially correct, and that the conclusions and recommendations are conceptually and empirically defensible. We hope that the heuristic value of the study will be equally strong.

APPENDIX A

Coding Protocol

1) Full Reference
2) Referred to in
   a) Rogers and Shoemaker
   b) Rothman
   c) NSF
   d) Zaltman
   e) Havelock
   f) other
   g) regarding what characteristic
3) Author's and Journal's Field of Study
4) Abstract
5) Research Approach
   a) case study
   b) survey
   c) experiment
   d) theory
   e) secondary data analysis
6) Description of Innovation(s) Studied
   a) general description
   b) number of innovations studied
   c) area of innovation technology
7) Nature of Adopting Unit
   1) individual
   2) organization
   3) community
   4) society, nation, etc.

8) Unit of Analysis/*N*

9) Dependent Variable(s) and Definitions
   a) adoption decision or time of adoption, or adoption and implementation
   b) how measured
      1) rated by adopters
      2) rated by judges
      3) inferred
      4) profit and cost data, or other secondary data
      5) not applicable

10) Independent Variable(s) and Definitions
   a) specific innovation characteristic(s)
   b) number of characteristics
   c) other independent variables
   d) how measured
      rated by adopters
      rated by judges
      inferred
      profit and cost data (secondary)
      not applicable

11) Statistics Used
   a) descriptive
   b) correlations
   c) regression
   d) factor analysis
   e) discriminant analysis
   f) other statistics, specify
   g) no statistics used

12) Findings

13) Overall Conclusions

14) Comments

APPENDIX B

List of Characteristics

1) Relative advantage
2) Association with major enterprise
3) Clarity of results
4) Compatibility
5) Communicability
6) Complexity
7) Continuing cost
8) Cost
9) Divisibility
10) Ease of operation
11) Flexibility
12) Importance
13) Initial cost
14) Mechanical attraction
15) Observability
16) Payoff
17) Pervasiveness
18) Profitability
19) Radicalness
20) Rate of cost recovery
21) Regularity of reward
22) Reliability
23) Riskiness
24) Specificity of evaluation
25) Saving of discomfort
26) Saving of time
27) Scientific status
28) Social approval
29) Trialability
30) Visibility.

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