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ABSTRACT

This paper analyzes some of the problems of using diffusion models to formulate marketing strategies for new products. Though future work in this area appears justified, many unresolved problems limit its application. There is no theory for adoption and diffusion processes; such a theory is outlined in this paper. The present models are too restrictive and fail to include the variables that a marketing manager has at his disposal. Six models that remove some theoretical and methodological restrictions are presented. The marketing implications for the assumptions in the models are discussed, and estimation problems are considered. (Author)

SOME PROBLEMS IN USING DIFFUSION MODELS FOR NEW PRODUCTS

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INTRODUCTION

A marketing manager has a limited number of variables under his control with which to influence the sales of a new product. Every new product is an innovation, and the diffusion of its adoption through its intended market is necessary if the product is to be successful. A thorough understanding of the adoption and diffusion processes and their relation to the decision variables under his control would appear to be useful to the marketing manager in planning new product introduction. Indeed, the promise and potential of applying theories of the diffusion process to new product introduction have increasingly interested those who do marketing research ([9], [24], [25], [27], [29], [44], [48], [50]) and those who write marketing books (e.g., [32] and [54]). Though we agree with the optimism of some of these writers, our research efforts have rendered us skeptical about the immediate practical value of these ideas. This skepticism results from our estimate about the significance of the unsolved problem in the use of diffusion models for new product introduction. In this paper we shall analyze these problems.

Following Katz, Levin, and Hamilton ([30], p. 237), we define the diffusion process for economic goods as the adoption over time of a specific product, by customers who are linked by channels of communication to a given social structure and by a given system of values or culture. We shall consider adoption as a decision process on the part of an adopter. The adoption process is initiated when the change agent causes the adopter to become aware of the innovation. The decision to adopt or not adopt is determined by a potential adopter's perceived net utility of adopting. The potential adopter's perceptions are influenced by the change agent, the product, the adopter's linkage by channels of communication to a social structure, and by the adopter's culture.

Different assumptions underlying the norms, social structure, sources and effectiveness of adoptive influence, etc., result in different models of diffusion. This paper considers variables and models which reflect these possibilities. The variables considered in the paper are given in Table 1 and some models are presented in Table 2. There are both deterministic and stochastic models in the diffusion literature. In this paper only deterministic models are considered. Several stochastic models are described in another paper [6]. These tables are placed at the beginning to suggest the scope of our theory and to provide a guide to the development of this paper. The ordered list of equations in Table 2 is the order in which the models are presented in the text.

Table 1 about here

Table 2 about here

TABLE 1

Variables Used in Models

Variable	Definition of Variable
c	Time rate of contact between adopters and others in the population, $0 \le c \le 1$. It is a decreasing function of the degree of segmentation.
g	Net growth rate of population
k_1'	A measure of the effectiveness of adopter - non-adopter contacts in creating zero differential evaluation.
k_2	A measure of the effectiveness of influences other than adopter - non-adopter contacts in creating zero differential-ial evaluation.
$k_1 =$	$k_1'N$ for fixed population N k_1 for populations with net growth
n	Numbers of adopters
N	The size of the population; i.e., the number of potential adopters who would adopt <u>some</u> price-quality variant of the innovation if their differential evaluation were zero.[a]
r	Rate at which members of population are removed.
X	The proportion of N who would adopt a <u>particular</u> price-quality variant of the innovation if their differential evaluation were zero.
η	The utility elasticity of adopter activity levels

a. Adoption of an innovation entails risk. We assume that this risk leads potential adopters to act as though they perceive the benefits of adoption to be less than as perceived by the change agent and the costs of adoption to be greater than as perceived by the change agent. We call this apparent difference in perception differential evaluation.

TABLE 2

Some Deterministic Models of Diffusion Processes

Assumptions	Model	Asymptotic Limit[b/]	References (including manuscript equations)
N constant, $c=1$, $X=1$, $k_2=g=r=0$	$n'=k_1n(1-n/N)^a$	1	[13],[38], equation(2)
N constant, $c=0$, $X=1$ $k_1=g=r=0$	$n'=Nk_2(1-n/N)$	1	[13], equation (4)
N constant, $c=1$, $X=1$ $g=r=0$	$n'=k_1n(1-n/N)+k_2n(1-n/N)$	1	[13]
N constant, $c=1$, $X\leq 1$, $k_2=g=r=0$	$n'=k_1Xn(1-n/XN)$	X	[26]
N not constant, $c=1$, $X=1$, $g\neq r\neq 0$, $k_2=0$	$n'=k_1n(1-n/[N(0)\exp(gt)]-rn$	$\frac{k_1}{k_1+g+r}$	[42]
N constant, $c\leq 1$, $X\leq 1$, $k_2=g=r=0$	$n'=Xck_1n(1-n/XN)$	X	equation (18)
N not constant, $c\leq 1$, $X=1$, $k_2=0$ $g\neq r\neq o$	$n'=X\{ck_1n[1-n/(XN(0)\exp(gt))]-rn/X\}$	if $ck_1X>g+r$, then $X[1-(g+r)/ck_1X]$ if $ck_1X\leq g+r$, then the limit is zero	equation (20)
N constant, $c=0$, $X\leq 1$, $g=r=0$	$n'=Nk_2X(1-n/XN)$	X	equation (22)
N not constant, $c=0$ $X\leq 1$, $g\neq r\neq 0$	$n'=X[k_2(N(0)\exp(gt)-n/X)-rn/X]$	$Xk_2/(k_2+g+r)$	equation (24)
N constant, $c\leq N$, $X\leq 1$, $g=r=0$	$n'=X[ck_1n(1-n/XN)+k_2N(1-n/XN)]$	X	equation (26)
N not constant, $c\leq 1$, $x\leq 1$, $g\neq r\neq 0$	$n'=X\{ck_1n[1-n/(XN(0)\exp(gt))]$ $+k_2(N(0)\exp(gt)-n/X)-rn/X\}$	$\frac{Xc_1k_1-k_2-g-r+\sqrt{y}}{2ck_1}$ where $y=4k_2ck_1X+(ck_1X-k_2-g-r)^2$	equation (28)

a/ The variables n and N are assumed to be continuous and time dependent unless otherwise stated in the first column. The symbol n' means $\frac{dn}{dt}$. All constants are assumed non-negative.

b/ The proportion of adopters in population at $t=\infty$. N(0) is the size of the population at t=0.

The problems involved in understanding the diffusion of innovations can be placed in perspective if we consider the diffusion processes implied by the first two equations in Table 2. The first, and most often used, is the simple logistic. If n is the number of adopters in a population of size N, the model states that the rate of increase in the number of adopters is proportional to the product of the number of adopters n and the number of potential adopters, N-n. Or, $n' = \frac{dn}{dt}$ is defined by

$$(1) \qquad n' = k_1'n(N-n).$$

For various theoretical reasons equation (1) may be expressed as

$$(2) \qquad n' = k_1 n(1-n/N),$$

where $k_1 = Nk_1'$.

Several questions about equation (1) must be resolved. First, what are the determinants of the value of k_1? Second, is N a constant or a variable? That is, is there entry and exit into and out of the population? Third, is every member of the population a potential adopter? Fourth, why is n' proportional to n(N-n)? Fifth, how does the change agent affect (1)? Sixth, what constitutes an adoption? Each of these questions constitutes a set of problems when diffusion models are used to introduce new products.

For example, n' is assumed proportional to n(N-n' by analogy to early models of the spread of epidemics. Consider n persons with a communicable disease with direct contact with N-n susceptibles. There are n(N-n) possible contacts which could result in the spread of the disease. Each contact has an average contagiousness of k_1. Thus, the increase in the number of diseased individuals is $k_1 n(N-n)$. Structurally, equation (1) assumes an all-channel social structure (cf.[36], [37]) and we are ultimately dealing with influence on adoption decisions rather than contagion. This structural assumption is really quite inappropriate when the structure is segmented. For most social structures, and particularly for large ones, the number of channels is considerably lower than $n(N-n)$ and the channels vary in their ability to influence. Methods for correcting violations of this assumption are discussed later in the paper.

The model of equation (1) assumes that there are no processes influencing the potential adopters except those which result from contacts with adopters. A second diffusion process occurs when there is no influence of adopters upon potential adopters and the sources of influence to adopt are external to the potential adopters. In this case, the source of influence is the change agent, where we consider any source of influence other than prior adopters to be a change agent (e.g. salesman, point of purchase display, advertisements, etc.). For this situation, then, the rate of increase in the number of adopters is directly proportional to the number of potential adopters, or

$$n' = k_2(N-n). \tag{3}$$

This is rewritten as

$$n' = Nk_2(1 - n/N). \tag{4}$$

A diffusion process described by equation (3) raises the same sort of questions as the process described by equation (1). These two represent two polar types. Equation (1) represents a process in which the influence is entirely due to the social structure; equation (3) represents a process in which the influence is due to change agents. Any impact of the social structure upon the adoption is negligible. Clearly, then equation (1) is preferable for small, unsegmented groups and for products where potential adopters seek and receive information from adopters; and equation (3) is better for large, segmented groups and for products where potential adopters do not seek or receive information from adopters. For example, equation (1) is probably a reasonable model for studying the diffusion of a producers durable within a segment of an industry and equation (3) for a nationally advertised consumer item.

These two polar diffusion models yield quite different diffusion curves. Solving equation (1) with the boundary condition that at $t = 0$, $n = 1$, we have

$$\frac{n}{N} = \{1 + \exp(a - \frac{k_1}{N} t)\}^{-1} \tag{5}$$

where $a = \log_e(N-1)$. This equation is often rewritten as

$$\log_e \frac{n}{N-n} = -a + \frac{k_1}{N} t \tag{6}$$

for the purpose of estimating a and k_1. A plot of equation (5) yields an "S" shaped graph or logistic. Beginning with a small initial value (attained without contacts with prior adopters) the percentage of adopters increases slowly, accelerates, and then levels off at 100 percent. All the equations in Table 2 for which $k_1 \neq 0$ represent processes with diffusion curves of the "S" shape.

The graph of equation (5) looks like the distribution function of the normal distribution. The similarity has led to many incorrect statements in the diffusion literature. There are, in fact, many functions generating the same "S" shape. For example, the distribution function of any unimodel probability density function is "S" shaped.

Solving equation (3) with the boundary condition that at $t = 0$, $n = 0$, the proportion of the population who have adopted at time t is given by

$$n/N = 1 - \exp(-k_2 t). \tag{7}$$

The graph of equation (7) is a modified exponential with unit asymptote. Unlike equation (5) the curve is not "S" shaped because the second derivative is everywhere non-positive if $k_2 \geq 0$. The equations in Table 2 whose value of $k_1 = 0$, represent processes having the modified exponential shape diffusion curve.

These simple models have been used successfully in empirical studies. The differential equation for the first process has been used by Mansfield [38] to study the diffusion of selected industrial goods, and by Coleman, Katz, and Menzel [13] for the diffusion of an ethical drug among groups of socially integrated doctors in three small and medium sized towns. The differential equation for the second process has been used by Coleman, et. al., to represent the adoption of the same ethical drug by socially isolated doctors [13]. It would appear, therefor that diffusion models can be an aid in the introduction of new products. The high failure record of new products would seem to make any such aid valuable. But, to use a diffusion model, the marketing manager needs to know more about these processes. He must determine the appropriate model for his problem. His product and customers may differ from those studied by Mansfield and Coleman, _et_. _al_. To be able to translate the implications of this model into price, product, and promotion strategies, a theory, as well as a collection of models, is needed.

Unfortunately, theories of adoption and diffusion processes are poorly developed in related literature. A theory of these processes is outlined in the next section. This section is followed by six models which remove some of the restrictive assumptions in the diffusion models of equations (1) and (3). To avoid any misunderstanding, we want to emphasize the modesty of our theory and models. Neither the theory nor the models solve the problem of how to use diffusion models to introduce new products more successfully. We believe, however, that our analysis highlights substantive conceptual and methodological issues. As the title of this paper suggests, problems do arise when diffusion models are utilized for introducing new products.

A THEORY OF THE ADOPTION AND DIFFUSION PROCESSES

To the potential adopter a new product or innovation represents change, but he may be unclear about the nature of the change and its consequences. The decision to adopt an innovation entails risk. The creation and reduction of this risk by the change agent, the potential adopter's culture, and his role in a social group are all important factors in the adoption and diffusion processes.

1. Adoption Creates Change

Any innovation represents change. The decision to adopt depends upon the perceived net economic and psychosocial benefits involved. There are two important aspects to change induced by adoption of the innovation: (1) Its nature and (2) its consequences. The important factor is how the potential adopter perceives the net benefits of adoption.

An innovation is to be compared with that for which it is a replacement. An innovation may be an idea, a technique, a process, or a new product. The following discussion will evolve in terms of a new product innovation. The discussion, however, is not limited to this specific category. An innovation, when adopted, usually results in a change in the activities of the buyer. Some activities will be discontinued, some unchanged, and some added. In general, suppose there are m dimensions to describe the pre-adoption and post-adoption activities.

These m dimensions describe a vector space $X^m = (X_1, X_2, \ldots, X_m)$ where the $X_i \varepsilon X^m$ are levels of activity of type i. The decision to adopt takes place over a period of time. At any time, t, the position of a potential adopter is a vector of numbers representing the level of activity on each dimension, $X_i \varepsilon X^m$.

Let $X_p(t) = (x_{1p}(t), x_{2p}(t), \ldots, x_{ip}(t), \ldots, x_{mp}(t))$ be the position in X^m of a potential adopter t time units after the innovation is introduced if he does not adopt. Let $X_a = (x_{a1}, x_{a2}, \ldots, x_{ai}, \ldots, x_{am})$ be this position if he were to adopt.

Ordinarily, a potential adopter will not <u>know</u> X_a. He may consider X_a as a random variable $X_a(t)$ to describe the set of values of X_a which has an associated subjective distribution. During the decision period his estimates of X_a may change with added information. Let $\bar{x}_a(t) = (\bar{x}_{1a}(t), \bar{x}_{2a}(t), \ldots, \bar{x}_{ia}(t), \ldots, \bar{x}_{ma}(t))$ be the potential adopter's point estimate perception of his position if he were to adopt t time units after the innovation is introduced. Let $\sigma(t) = (\sigma_1(t), \sigma_2(t), \ldots, \sigma_m(t))$ be the standard deviation vector of this distribution, $X_a(t)$. Note that $\bar{x}_a(t)$, and $\sigma(t)$ may change as the potential adopter receives new information. $X_p(t)$ depends on the state of his current preadoption situation, which also may change.

The nature of the change at time t is the difference between $X_p(t)$ and $X_a(t)$. It is important to recognize that the nature of the change will itself change over time.

The potential adopter is assumed to have a utility function, $U(X^m)$, defined on X^m - on the activities, not the associated goods. The dimensions of X^m are defined such that,

$$U(x_1, x_2, \ldots, x_i^o, \ldots, x_m) \geq U(x_1, x_2, \ldots, x_i, \ldots, x_m)$$
$$\text{if } x_i^o \geq x_i \ (i = 1, 2, \ldots, m).$$

The vector, $\bar{x}_a(t)$, is not the vector on which the decision to adopt or not will be directly based. It is reasonable for a potential adopter to require before adopting that the probability be low that adopting an innovation is a mistake in that he be worse off as a result of adopting. $U(\bar{x}_a(t))$ exceeding $U(x_p(t))$ is not sufficient for adoption since $\bar{x}_a(t)$ is not held with certainty.

The distribution on $X_a(t)$ implies a distribution for a random variable $U_a(t)$. Let $\bar{U}_a(t) = U(\bar{x}_a(t))$ be the potential adopter's point estimate of the true value of U if he were to adopt. Let $\sigma_u(t)$ be the standard deviation of the random variable, $U_a(t)$. Note: $\bar{U}a(t)$ is not necessarily equal to $EUa(t)$.

One way for a potential adopter to handle his uncertainty regarding X_a and $U(X_a)$ is to require a degree of confidence, $1 - \alpha_u$, that $U(X_a)$ not be less than the value of U on which he bases his decision to adopt or not. He may do this by choosing z_u such that

$$P(U(X_a) < \bar{U}_a(t) - z_u\sigma_u(t)) < \alpha_u$$

Define the <u>consequence</u> of the change, $\Delta U(t)$, as

(8) $\Delta U(t) = \bar{U}_a(t) - z_u\sigma_u(t) - U(X_p(t))$.

Adoption will occur if $\Delta U(t) > 0$, i.e., if the consequence of the change in which uncertainty is accounted for is positive.

Both the nature of the change and its consequence are defined for an individual potential adopter. The change induced by the innovation may differ among potential adopters. Each adopter may misperceive the nature and consequences associated with adopting an innovation. (This view of an innovation as a causal chain is similar to that of Lancaster [34], p. 133.)

The marketing manager and his change agents must assess the new product in terms of this causal chain for the potential adopter. They should be aware that the consequences of adoption depend on the potential adopter as well as the product. Location and social affiliation of the adopter may be important (cf. Coughenour [15], Erasmus [19], and Fliegel and Kivlin [23]). For some innovations the dominant influence may be economic. Griliches [26], for instance, found that in spite of wide differences in education and income among farmers, the variance in adoption rates of hybrid corn among regions could be explained by regional differences in the profitability of adopting hybrid corn. Even here, however, some effects of adopting were non-economic. The planting of hybrid corn may have altered a farmer's relation with his neighbors, suppliers, and government agencies.

Other innovations, in other circumstances, however, may result in a lower weighting of the economic aspects. This is especially true of innovations which are fads or fashions [39]. On the other hand, Evan and Black [20] report the encouraging result that good staff reports are more likely to be accepted than bad ones. As we shall see, the culture, social structure, and role of the adopter can alter both the perceived nature of the change and its consequences.

2. Risk Creates Differential Evaluation

A potential adopter will usually know neither the nature nor the consequences of adoption introduced by some change agent.

He may tend not to accept at face value the claims of the change agent about $X_a(t)$ and $\Delta U(t)$, especially if he feels the change agent may know neither the nature or the consequences of the change which results from adoption by a particular potential adopter.

Specifically, let us assume a potential adopter "knows" $X_p(t)$ and $U(X_p(t))$ but is unsure of $\bar{x}_a(t)$ and hence $U(\bar{x}_a(t))$. By "knows" we mean that he can compare any new position $\bar{x}_a(t)$ with $X_p(t)$ and arrive at a judgment of $\Delta U(t)$. He is unsure of $\bar{x}_a(t)$ and may, in addition, be unsure of the value of any component utility function, $U_i(\bar{x}_{ia}(t))$ in the range of $\bar{x}_{ia}(t) \varepsilon X_i$ assumed taken after adoption. One of his problems is to secure "better" information. Hence, adoption implies some perceived risk by the potential adopter. The proceedure described above for handling this risk involves acting as though the perceived utility of the post-adoption activities was less than the point estimate of this utility, $U(\bar{x}_a(t))$. An alternative way of handling the risk would be to compute the utility of the post-adoption activities as though the value of each activity were less than the point estimate of that value. For each dimension of $\bar{x}_a(t)$ the potential adopter would require a degree of confidence, $1-\alpha_i$ $(i=1,2, \ldots, m)$ that the true value x_{ai} be greater than or equal to the value on which he bases his decision to adopt. The potential adopter will determine values $z_1, z_2, \ldots, z_m$ such that

(9) $P(X_{ai} < \bar{x}_{ai}(t) - z_i\sigma_i(t)) < \alpha_i \quad (i = 1, 2, \ldots, m).$

The greater the perceived risk, the smaller the value of α_i and the larger the values of z_i and $\sigma_i(t)$. The larger the values of z_i and $\sigma_i(t)$, the greater the hedge against the risk. Due to the method of defining the dimensions of X^m in such a way that the greater the distance from the origin, the greater the utility, dimensions involving benefits have positive values of

z_i and dimensions involving costs have negative values of z_i. Since the benefits of an innovation may be less well known (greater $\sigma(t)$) than costs, for any given α_i and z_i, there may be a greater hedging for the benefit dimensions than for the costs. Hence, benefits and costs, as well as different dimensions in X^m may be differentially evaluated according to the circumstances.

The major conjecture of our theory is that the processes of adoption and diffusion are equivalent to reduction of differential evaluation. All processes and parameters relate back to the creation or reduction in the level of differential evaluation. For each dimension, the degree of differential evaluation is, for each α_i,

$$(10) \quad D_i(t) = x_{ai} - [\bar{x}_{ai}(t) - z_i \, \sigma_i(t)] \quad (i = 1,2, \ldots, m).$$

There are, therefore, three major parameters which are important to understanding any adoption and diffusion process: $\{\alpha_i\}$, $\{z_i\}$, and $\{\sigma_i(t)\}$. Let us consider each in turn.

Some activities are more important to him than others. For example, the speed of a web offset printing press may be more important than the frequency of lubrication. Let the importance of an activity level X_i to his decision be defined by its elasticity, η_i, where

$$(11) \qquad \eta_i = \frac{\partial U_i(x_i)}{\partial x_i} \cdot \frac{x_i}{U_i(x_i)} .$$

Defined on η_i is a function, α_i, where

$$(12) \qquad \alpha_i = f(\eta_i), \ \frac{\partial f}{\partial \eta_i} < 0.$$

The value of $1 - \alpha_i$ is the degree of confidence required by the potential adopter of not accepting a false estimate of $\bar{x}_{ia}(t)$. Equation (12) states that the greater the elasticity of his utility function $U_i(x_i)$ for a change in x_i, the greater the degree of confidence required for that activity level. The value of α_i is the area in the left tail of the distribution with variance $\sigma_i^2(t)$. Given the distribution, a confidence interval can be defined for accepting change agent's value of x_{ai}. From the value of α_i, a standard score z_i may be computed. Thus, in order to take into account the required level of confidence, $1 - \alpha_i$, the innovation position $\bar{x}_{ai}$ is shifted to $\bar{x}_{ai}(t) - z_i\ \sigma_i(t)$. If the true position, should he adopt, is x_{ai} rather than $\bar{x}_{ai}(t)$, the total gap is defined by equation (10), or the degree of differential evaluation, $D_i(t)$.

Furthermore, the information received from the change agent suggests that the nature of the change for that activity is to move from level $x_{ip}(t)$ (pre-adoption) to $\bar{x}_{ia}(t)$ (the position he perceives should he adopt at time t). He is uncertain whether $X_i = \bar{x}_{ia}(t)$ as claimed by the change agent. The value of $\bar{x}_{ia}(t)$ is a point estimate of X_i where X_i is a random variable with unknown distribution. He will, in general, be uncertain about both the underlying probability density function for <u>each</u> value $x_i \epsilon X_i$ and the distribution of the range of values of $x_i \epsilon X_i$. Thus, he is faced with an unknown random variable of a random variable. Let the compound random variable have variance $\sigma_i^2(t)$. Assume that $\lim_{t \to \infty} \sigma_i^2(t) = 0$ or that he will eventually obtain a zero variance estimate of X_i for his particular situation. The greater the novelty of an innovation, the greater the value of $\sigma_i(t)$. Ceteris paribus the greater the strangeness or novelty of an innovation to a potential adopter, the greater the degree of differential evaluation, $D_i(t)$. Finally, as $t\to\infty$, the degree of differential evaluation, $D_i(t)\to 0$.

Whenever, the utility function of a potential adopter is stable over his decision period for the dimensions relevant to the innovation, α_i and therefore, z_i, are constant and the degree of differential evaluation approaches zero for each dimension.

The vector on the basis of which the adoption decision is made is,

$$\bar{x}_{da}(t) = (\bar{x}_{a1}(t)-z_1\sigma_1(t),\ \bar{x}_{a2}(t)-z_2\sigma_2(t),\ \ldots,\ \bar{x}_{am}(t)-z_m\sigma_m(t)).$$

Consequently, the consequence of the change, $\Delta U(t)$, (cf. equation (8)), can be alternatively defined as

(13) $\quad \Delta U(t) = U(\bar{x}_{da}(t))-U(x_p(t)).$

Adoption occurs whenever $\Delta U(t)>0$, i.e., if the consequence of the change, in which uncertainty is accounted for, is positive. Note that $\bar{x}_{ai}(t)-z_i\sigma_i(t)$ is by equation (10) equal to $x_{ai}-D_i(t)$. Let $D(t) = (D_1(t), D_2(t), \ldots, D_m(t))$
Hence, an alternative definition of $\Delta U(t)$ is;

(14) $\quad \Delta U(t) = U(X_a-D\ (t))-U(X_p(t)).$

If $U(t)$ is linear or approximately linear in the interval $(X_p(t),X_a)$, we have

(15) $\quad \Delta U(t) = U(X_a) - U(X_p(t)) - U(D\ (t)).$

Since, X_a is determined by the innovation and $X_p(t)$ by that which the innovation is changing, the major problem in understanding adoption and diffusion processes is the determination of $D_i(t)$ for $t = 1,2, \ldots, m$. Thus, the most important feature of a theory of adoption and diffusion are the determinants of the degree of differential evaluation, $D_i(t)$.

For each dimension, $D_i(t)$ decreases as increased information leads to a reduction in uncertainty, $\sigma_i(t)$, unless the increased information leads to a worsening of $\bar{x}_{ai}(t)$ that more then offsets the reduction in $\sigma_i(t)$. Reduction of $D_i(t)$ reduces $\Delta U(t)$; but is is possible for $D_i(t)=0$ and not get adoption because $U(X_a) < U(X_p(t))-U(0)$. Furthermore, it is possible to get adoption if $D_i(t)\neq 0$, provided $U(X_a)-U(X_p(t)) > U(D_i(t))$.

It is now possible to define the concept of an innovation. An innovation is that which yields differential evaluation in a potential adopter and the degree of the innovativeness of an innovation is the degree of differential evaluation. In this context, as the length of the decision period increases and $D_i(t)$ becomes smaller, so does the innovativeness of the original innovation. What started out as a major innovation may become minor in its innovativeness by the time it is finally adopted. In fact, the main purpose of the adoption decision process is to reduce the innovativeness of an innovation before adopting it. The major difference between a trivial innovation like a fad and a new machine costing millions of dollars is that fads are often adopted with greater amount of differential evaluation.

This analysis of the differential evaluation phenomenon is in terms of an individual potential adopter's utility function and his current and expected position. It represents a generalization of Bauer's perceived risk concept [1]. The volume edited by D. Cox ([16]) contains examples of many types of differential evaluation and their determinants for consumer products. The concept of differential evaluation is multidimensional and dynamic and, hence, is more appropriate for the analysis of diffusion.

Before proceeding to the mechanisms influencing differential evaluation, two points should be made. First, one can measure $D_i(t)$ for an individual by noting the discrepency between the estimate of the change agent, which we may assume to be approximately correct, and the apparent estimate of the individual. It is the "gap", $D_i(t)$, which can be observed at any time. It would take a panel type of study to trace out the time path of $D_i(t)$. With a single potential adopter it would be very difficult to estimate a potential adopter's α_i statistically unless his utility function were known in advance. The theoretical framework provided can aid in the diagnosis of each potential adopter's resistance by illuminating the underlying mechanisms. Secondly, at the more aggregate level of diffusion processes, the presence of differential evaluation is manifested in the difference in the evaluation of the parameters k_1 and k_2 in equations (1) and (3) respectively. Suppose, for example, that k_1 of equation (1) is a linear function of relative profitability, π, and relative size, S, for a class of industrial goods defined

(16) $\qquad k_1 = -.59+.530\,\pi-.027S$.

This equation defines the value of k_1 given the values of π and S. By equation (6) the value of k_1 determines the rate of diffusion.

We could measure the effects of differential evaluation by comparing estimates of π and S by the change agents with the estimates of the potential adopters. This equation (adapted from Mansfield ([38], p. 752) states that the greater the value of relative profitability, the greater the value of k_1; the greater the value of relative size (initial investments in the innovation divided by average total assets at the time of the introduction of the innovation), then the lower the value of k_1. Hence, if the change agent estimates have a higher value of π and a lower value of S than the potential adopters, differential evaluation exists and its effects will be measured by the differences in the rates of diffusion, k_1.

Because adoption usually requires a reduction in differential evaluation below its initial level, the adoption process takes time. The process may be divided into stages. One such possible division involves five steps:[1]
(1) Awareness, (2) interest, (3) evaluation, (4) trial, and (5) adoption. The time interval may consist of years or seconds. For example, Carter and Williams [10] found a 40-year time lag between the introduction of the tunnel oven in the pottery industry and its widespread use. On the other hand, when a consumer becomes aware of a new breakfast cereal in a store, the decision to buy may be almost instantaneous.

Movement from one stage to the next requires an information search and a decision. An important finding of previous research in this area is that different information sources are more potent at different stages - although this is not uniform for innovations. ([23], [47]).

3. The Determinants of Differential Evaluation and Its Reduction

Reduction of differential evaluation occurs as acquisition of information reduces uncertainty regarding the innovation. In this section we discuss the sources and kinds of information necessary for the reduction of differential evaluation. Then we consider the factors which determine the effectiveness of this information.

The source and kind of information determine the pattern of diffusion. When information from contact with prior adopters is necessary for adoption, and when information from sources outside the potential adopter's relevant social group increases the efficacy of contact information, the pattern is like that represented by equation (1) or one of the more complex interaction models in Table 2. When information acquired from contact with prior adopters is not necessary, and information from sources outside the potential adopter's relevant social group alone can lead to adoption, the diffusion pattern is like that of equation (3) or one of the simpler non-interaction models in Table 2.

Our discussion of factors which determine the effectiveness of information in reducing differential evaluation will be in terms of how these factors affect three variables which appear in diffusion models considered in this paper, k_1, k_2, and c. The parameter, k_2, is a measure of the effectiveness of information provided by sources external to the potential adopter's relevant social group. The parameter, k_2, appears in models in which it is assumed that at least some adoptions occur without contact with prior adopters. The parameter, c, is a measure of the contact rate among members of the relevant social group or the "degree of segmentation" (cf.[7]). The parameter, c, appears in models in which it is assumed that at least some adoptions occur in response to contacts with prior adopters within the relevant social group.

a. The Source and Kind of Information Received

The potential adopter may recieve promotional or institutional information from sources external to his social group, e.g., advertisements, point of purchase displays, magazine articles, and change agents such as detail men or salesmen. Or, he may receive information from contact with members of his social group. The kinds and sources of information necessary for the reduction of differential evaluation depend upon the potential adopters, the relation of the adopters to the change agent, the relation of the adopter to his relevant social group, and on the product. External information sources will tend to be adequate when the potential adopter feels he has a great deal of knowledge regarding the product class of the new product, when a relationship of trust exists between the change agent and the potential adopter, when the potential adopter is isolated from a social group relevant for the product, when the product is fairly simple, and finally when adoption will produce little impact on the norms of the social group relevant to the product.

Contact with members of the relevant social group may be necessary when the potential adopter's lack of knowledge and the product's complexity makes externally provided information unclear, or when adoption of a radical innovation significantly relates to the norms of a potential adopter's social group. For a doctor considering the use of a new drug, or a farmer considering the use of a new seed, the externally provided information may be accurate and in great detail. But it may still be difficult to know how this objective and promotional information relates to his specific situation. For example, the doctor may be cautious in adopting a new drug because past experience has taught him that unanticipated harmful side effects may occur, or the farmer may not know how a new seed will grow in the soil of <u>his</u> farmland. If another doctor in the first doctor's immediate group has tried the new drug and reports success, or if a neighboring farmer with similar soil conditions has successfully adopted the new seed, two new types of information are provided, <u>experiencing</u> and <u>legitimizing</u>. In the doctor's case, experiencing information on the part of a colleague provides him with data on how the new drug works in his particular situation. These "clinical" data may not be objectively as good as published information, but they are more related to his own case, and can reduce his perceived risk, and thereby his differential evaluation. This local source of information gives him additional and more detailed information about the nature of the change, and about costs and benefits of <u>his</u>

possible adoption. Knowing that a new drug works in his particular situation provides more detailed evidence than the knowledge that it should work, <u>ceteris paribus</u>. In terms of differential evaluation (equation 13) experiencing information tends to decrease $\sigma_i(t)$ and legitimizing information tends to increase α_i and hence decrease z_i.

If an innovation is radical (large $\sigma_i(t)$ and small α_i), a potential adopter may hesitate to adopt it if, within his reference group, it is potentially unacceptable with respect to the norms of his group. The experiencing information may come from a group deviant who is not legitimate from the group's point of view. There is still a social risk. But if a high status or prominent group member adopts, he receives legitimizing information. Legitimizing information reduces the social cost of adoption. It permits him to reduce the differential evaluation by allowing him to shift the possible cost to the group. If many of his reference group adopt an innovation, he may adopt more readily because of his concern for not being a deviant member himself. It is the group to which he belongs that provides much of the experiencing and legitimizing information which affects his adoption. As a result, the social system and its norms has an impact on his decision to adopt.

b. <u>Factors Which Affect the Values of k_1, and k_2</u>

Both k_1 and k_2 are measures of the effectiveness of information in reducing differential evaluation. Factors which affect the values of both are:

1. the activities of the seller-change agent, and his relation to potential adopters.

2. the cost of search for information necessary to reduce differential evaluation relative to the potential benefits from that search.

3. the innovation's relation to other products

4. the ease or difficulty of breaking adoption of the innovation into parts.

The seller-change agent's activities are instrumental in bringing an innovation to the attention of a potential adopter. His efforts form an important part of the adoption process whether or not the adopters are linked together socially. Many studies have demonstrated that a positive relation exists between the level of a seller-change agent's activities and his rate of obtaining adoptions. By increasing his effort, the seller-change agent can reach more potential adopters; he can reach them more than once and thereby reinforce previously provided information; and he can tailor the information provided to the needs of different adopters at different stages of the adoption process. The characteristics of the seller-change agent are also important (cf. Rogers [45], pp. 254-284). A relationship of trust between the seller-change agent and potential adopters built up by repeated contacts and relating to several products, can reduce differential evaluation. This is one reason why many firms emphasize their brand or company names.

As a potential adopter moves from the awareness stage to the adoption stage, he engages in information search. Search will continue if the perceived cost of search is less than the expected benefit. Thus the relative cost of search affects the rate of differential evaluation reduction. Many products are not adopted because the expected cost of search is felt to be greater than the increase in utility of the new product over other, already accepted, products in its class.

The cost of search relative to potential beneftis also determines the extent to which the seller-change agent can affect the rate of adoption. When the cost of search is low in relation to potential benefits, and the measurement of cost and benefits of adoption is clear, seller-change agent efforts will have relatively little effect. Where costs of search are high in relation to potential benefits or when the measurement of benefits is not obvious, seller-change agent efforts can have greater impact. Thus, Mansfield found that differences in adoption rates of twelve industrial goods were almost completely accounted for by differences in relative profitability and relative cost of adopting[3] ([38], p. 752). Griliches found that the variance among states in adoption rates for hybrid corn could be explained by differences in measures of profitability ([26], pp. 518, 521). These studies seem to say that there is very little room for marketing strategy. The best and only way to secure rapid and complete adoption of an innovation is to make adoption profitable and easy (small relative cost). We find such a conclusion unwarranted. These innovations were all important.

Adopting or not adopting them had a significant impact on the performance of the firms and farms involved. The firms' managers and the farmers must have been strongly motivated to determine if adoption of these innovations would be profitable. Marketing can be viewed as providing an information and evaluation service which the buyer of a good may or may not choose to use (Telser [49]). When adoption is very important, it may be most efficient for the buyer to expend sufficient resources to make his own information search and evaluation. In such a case, marketing effort by sellers above a minimal level may have very little effect on adoption and diffusion.

When the innovation is not very important relative to the cost of search to the buyer he may choose to rely more heavily on the service of the marketer. This is the significance of the distinction made by Holton [28] and others among unsought, convenience, shopping and specialty goods. A study by Haines on the adoption of a consumer non-durable shows that, with a product on which buyers might not be expected to engage in much search, seller-change agent effort can have an important effect ([27], pp. 649-650). In a study on the adoption of an industrial good -- a safety crane, it was found that the ambiguities involved in measuring potential costs and benefits of adopting permitted organizational processes to affect the adoption decision ([17], pp. 48-54). Here seller-change agent efforts may have been important.

The relation of an innovation to other products may affect the values of k_1 and k_2. Some innovations are <u>substitutes</u> or <u>functional replacements</u> for others previously adopted. For this type of innovation, previous knowledge should result in lower differential evaluation. Some innovations are complementary goods. If the other good has produced satisfaction, then the degree to which the innovation can increase the net utility of the other good, dictates whether the other good will receive low differential evaluation. Other products are <u>functionally tandem</u> to another product already accepted. For example, computer software is functionally tandem to computer hardware. Lithographic plate innovations which allow longer press runs are tandem to web offset printing presses. Some innovations are <u>technologically tandem</u> to prior innovations, in that knowledge of the prior innovations yields knowledge of the later one. For example, hybrid sorghum was technologically tandem to hybrid corn. Functionally or technologically, tandem innovations have lower differential evaluations for those with the prior product and hence should diffuse more quickly for these potential adopters. For example, hybrid sorghum has diffused faster than hybrid corn.

Some innovations can be introduced in stages or in separable pieces. Each piece represents a smaller change of activity than the entire innovation. Differential evaluation of an innovation can be reduced by piece-meal introduction of the parts for two reasons. First, the first part itself has lower differential evaluation than the total because adopting entails less risk, and second, once the first part has been successfully used, the differential evaluation of the remaining parts is reduced. The strategy for introducing change in increments is used in the computer industry and by management scientists attempting to get managerial acceptance of a machine or a new technique.

Sometimes an innovation is not adopted because the potential adopter believes there may be a subsequent innovation which will be better than the present innovation. Or, there may be currently available an alternative innovation which is perceived as being better. For example, a steel manufacturer may believe a new innovation will have a payout period of eight years and feel that within the next three years a competitive new innovation having a payout period of four years will become available. Or, he may not adopt because there is presently available a competitive innovation with a five year payout period. A housewife might not adopt a new fad because she feels that she will only experience limited use before it is replaced. This point is often overlooked by sociologists like E. Robers ([47], p. 171) who states:

> Laggards are the last to adopt an innovation. They possess almost no opinion leadership. Laggards tend to be frankly suspicious of innovations, innovators, and change agents. Their advanced age and tradition - direction slows the adoption process to a crawl. . . . While most individuals in a social system are looking to the road of change ahead, the laggard has his attention fixed on the rear view mirror.

Though in the eyes of a social change agent it may be contemptible to be a "laggard" or not to adopt an innovation, it is also possible that in many cases the laggard shows himself more cunning and shrewd by waiting until an anticipated improved version of an innovation reaches the market. In addition, the innovation may be unsound from the potential adopter's viewpoint despite the change agent's sincere belief in its consequences.

c. Factors Which Affect the Value of k_1, but not k_2

The factors which affect k_1, but not k_2 are those elements of the potential adopter's relevant social group which affect the differential evaluation and reduce the effect of different kinds of contacts. Wellin ([51], pp. 71-103) reports a two-year effort by two Peruvian public health workers to convince 200 families in a small rural community to boil their contaminated drinking water. It resulted in only eleven adoptions of this simple innovation. The eleven adopters were not integrated into the social structure of the community. The majority of non-adopters were supported in their non-adoption by their group affiliation which increased the importance of group values for them. The eleven non-integrated adopters had no influence on the majority.

To understand why one should expect the social system to influence adoption, we must consider the influence of the group upon the individual. Literature on small groups in social psychology (cf. Berg and Bass [6]) contains hundreds of studies on how group interaction can affect conformity and influence the behavior of an individual. A comprehensive survey of the literature is beyond the scope of this paper but, in regard to the adoption process, a few generalities are pertinent. Because of added reinforcements which do not exist in isolation, interacting group members experience faster and greater behavioral change than those who do not interact. Influence is a form of power. Entity A has <u>power</u> over B if (1) A can reward B or do that which will allow B to avoid punishment or a loss and if (2) B desires what A can do for or to him. Conformity results from the successful application of influence or power. Hence, it is not surprising that small-group studies have shown that the greater the rewards for conformity, the greater the incidence of conformity. At the group level, (1) conformity is greater in more attractive groups; (2) the more control a group exercises over an individual's rewards, the more will an individual conform to the group; (3) the greater the prior success of a group, the greater will be the current conformity.

Studies on the influence and leadership of an individual over a "follower" result in a similar series of statements. If we substitute the phrase "opinion leader" for the word "leader" in the above propositions, it is clear why Katz and Lazarsfeld [29] and numerous others have emphasized their importance in literature concerning the diffusion of innovations. One of the main sources of a leader's or group's influence or power is the ability to create uncertainty or to resolve the uncertainty in a novel situation and, by so doing, affect the distribution of rewards and punishments. In particular, the greater the demonstrated ability to solve another's problems the more will the person conform to the other's suggestion in a new, but related situation. Since an innovation creates a conflict in the mind of a potential adopter concerning both the nature and utility of a change, the opinions of a reference person or of a reference group can either increase or reduce the perceived utility of adoption. For example, in the study by Ryan and Gross [47] on the adoption of hybrid corn, the opinions of other farmers were very important in influencing the decision to adopt.

The relationships between culture and social structure may result in unanticipated results. Usually persons of higher socioeconomic status and those who frequently participate socially adopt innovations at a faster rate than those who do not. One would think, therefore, that Negro families in rural Georgia (in 1956) would adopt Salk polio vaccine more slowly than white families. Belcher [3] reported the opposite result. First, several months prior to the immunizations there was a scare regarding possible danger of the vaccine. More white families were aware of this source of high differential evaluation. Second, the immunizations were performed by the public health agencies which were thought to be only for Negroes and the poorest white groups. Third, the Negroes trusted the change agents involved because of extensive prior cooperation. Fourth, Negro schoolteachers made extensive efforts to push the vaccine program as did the non-white ministers (both from the pulpit and in individual contacts). This effort on the part of the change agents working through the Negro community encouraged adoption. "No such widespread efforts seemed to be present among the whites" ([3], p. 165). This study is one of many examples which demonstrates the impact of culture, social structure and the change agent on the acceptance of an innovation.

d. Factors Which Affect the Value of c

The factors which affect the value of contact frequency between adopters and potential adopters, c, are those linkages among potential adopters which determine the number and direction of communications. The model given by equation (1) assumes that every adopter is in contact with every non-adopter and that these contacts influence adoption. Due to geography, economics, class, life style and social segmentation, not every set of potential adopters is so closely related in structure. The relevant social structure will vary with the innovation even for the same population of potential adopters. The people with whom an adopter or potential adopter communicates regarding an innovation will usually depend on the product class to which the innovation belongs. The presence of segmentation reduces the number and rate of contacts from the maximum of $n(N-n)$ to $cn(N-n)$, where $0 \leq c \leq 1$. The value of c is determined by the structure of the population. For example, $c = 1$ in equation (1) implies an "all-channel" social structure where every adopter-potential adopter channel (all $n(N-n)$ of them) is open and equally used. If there is no structure connecting the population, $c = 0$.

Interconnections among adopters and non-adopters may be direct and indirect. Suppose a cost-saving innovation is introduced to a group of firms in an industry. It is not necessary for the management of the firms to be in direct communication to be influenced. A linkage can be provided by the market. Now, suppose two firms are competing for a common set of customers and the firm which has adopted the innovation is able to lower its price because of its cost-saving features. The second firm may lose sales to the firm with the innovation. The link here between the adopter and the non-adopter via the common set of customers can act as a powerful source of influence to encourage adoption. Or, the firms may be connected by means of craft labor unions where the workers "talk shop" and trade information about the innovation. This information can then be brought to management's attention by the workers.

MODELS FOR THE INTRODUCTION OF NEW PRODUCTS

To use the theory of diffusion as an aid in planning new product introduction, the marketing manager must have a model which represents the process of diffusion for the adoption of his new product. In this section we shall extend the simple models presented in the introduction with six models of the diffusion processes under different (and less restrictive) assumptions. Although these models (the last six of Table 2) are quite simple, we believe that, taken together, they represent a limited advance over what has preceded them. After presenting these models, we shall indicate why we think the advance they represent is limited. We shall then discuss some of the problems invovled in estimating the values of the parameters of these models.

1. The Variables

The variables appearing in our models are listed in Table 1. We discuss here some of the less obvious definitions which have not already been considered.

A key variable in a diffusion model is the number of adopters. If a new product has no close substitutes, a potential adopter is said to have adopted the product if he buys more than trial quantities of the class and if he shows a willingness to buy the new product whenever he buys a member of its class. The amount each adopter buys is assumed to be a function of his characteristics and of the product's quality-price characteristics. After adoption, differential evaluation is assumed to be zero, so that the quantity bought cannot be increased without changing the quality-price characteristics of the product. This would appear, superficially, to be unreasonable when a product has more than a single use. The correct perception may be attained with respect to some uses and not others; and information, by reducing differential evaluation with respect to the latter uses, may increase the amount each adopter buys. In this case, however, the product itself should be considered multiple, with multiple markets within which there are related but separate diffusion processes.

Given our definition of adoption, not every member of the population would adopt some quality-price variant of the new product even if there were no differential evaluation involved. Let X be the proportion of those who would adopt a particular quality-price variant of the new product. For any particular variant, XN is the potential market defined in terms of the numbers of adopters rather than sales. We shall assume throughout that X is constant. Assume also that tastes and other personal characteristics of consumers and the benefits and costs of potential industrial adopters are given and fixed. A potential adopter who gains a correct perception of the quality-price characteristics of the product will weigh the benefits and costs of adoption in terms of his given position, and decide whether to adopt on this basis. A seller can affect a potential adopter's perception of the product; but he cannot affect the benefits and costs of adopting without changing the objective quality-price characteristics of the product. This means that in the simple models to be described here it is the correct perception of the quality-price characteristics of a new product that is diffused.

2. Six Simple Models

For some products, in some populations, we may assume that, except for a few initial adoptions, all influence for adoption operates through contact with prior adopters. If we reasonably assume that not everyone in the population will adopt and not every adopter will contact every non-adopter in each time period, we get an equation which differs from equation (1) of the introduction in that $c \leq 1$ and $X \leq 1$. That is,

$$n' = Xck_1n(1-n/XN). \tag{17}$$

This is similar to the model used by Griliches for his study of the adoption of hybrid corn by farmers ([26], p. 504). It differs from his principally in that the effective contact rate is written as a product of two terms, c, a parameter, and k_1, a variable subject to influence by the marketing manager.

That equation (18) represents this process may be seen as follows. The number who have a correct perception of the new product is n/X. This includes those who have adopted, Xn/X and those whose perception is correct, but who have not adopted, (1-X)n/X. 1-n/XN is thus the proportion of potential adopters who at time t do not yet have a zero differential evaluation. The number of contacts with adopters and non-adopters made per period of time by adopters is cNn. Of this, cNn(1-n/XN) are with those who at time t do not have a correct perception of the product. Only $ck_1n(1-n/XN)$ are effective in creating a correct perception.

Only $Xck_1n(1-n/XN)$ lead to adoption.

The solution to this equation is:

$$(18) \qquad n/N = X[1 + (NX-n(0))/(n(0) \cdot \exp(-ck_1t))]^{-1}.$$

This is not defined for $n(0) = 0$ where $n(0)$ is the number of adopters at $t = 0$. This means that to get this "off the ground" some adopters must be attained by means other than contact with prior adopters. The solution describes an "S" shaped relation between n/N and t. The "slope" of the "S" is determined by Xck_1; and the asymptotic limit as $t \to \infty$ is X.

b. This model can be extended to incorporate constant rate entry and exit of population members. The new model is given by,

$$(19) \qquad n' = X\{ck_1n[1 - n/(XN(0)\ \exp(gt))] - rn/X\}.$$

Note that N of equation (18)has been replaced by $N(0)\ \exp(gt)$. $N(0)$ is the size of the population at $t = 0$. The parameter, g, is the <u>net</u> growth rate of the population of potential adopters. Also, the increase in the number of adopters brought about by contacts is partially offset by the loss of adopters through removal from the market. This removal is proportional to the number of adopters and is given by rn.

The solution to this equation is:

$$(20) \qquad n(t)/(N(0)\ \exp(gt)) =$$

$$X\left\{\frac{ck_1X - g - r}{ck_1X + X((ck_1X-g-r)/n(0) - cX/N(0))\ N(0)\exp[-(ck_1X-g-r)t]}\right\}.$$

As before, this is not defined for $n(0) = 0$ so that some initial adopters must be secured by some means other than contact with a prior adopter. If $ck_1X > g + r$ this solution will describe an "S" shaped relation between $n/(N(0) \exp(gt))$ and t, rising toward an asymptote, $X[1 - (g + r)/(ck_1X)]$ as t gets large. If $ck_1X < g + r$ then the asymptotic limit is $t \to \infty$ is zero.

c. For some products we may assume that all adoptions occur in response to influence from sources outside the population of potential adopters. If we reasonably postulate that not all who have zero differential evaluation will adopt, we get an equation which differs from equation (3) of the introduction in that $X \leq 1$. That is

$$(21) \qquad n' = Xk_2N(1 - n/XN)$$

$N(1 - n/XN)$ is the number who do not have a correct perception of the new product. The expression $k_2N(1 - n/XN)$ is the number who gain a correct perception in each time period. $Xk_2N(1 - n/XN)$ is the number who adopt.

The solution to this equation is,

$$(22) \qquad n/N = X[1 - \frac{NX - n(0)}{NX} \exp(-k_2t)].$$

This solution is a modified exponential which rises and approaches X asymptotically as t gets large.

d. This model can be extended by allowing net entry and exit at rates g and r respectively. Then, the differential equation for this more generalized model is,

$$(23) \qquad n' = X[k_2(N(0) \exp(gt) - n/X) - rn/X].$$

the solution to (23) is,

$$(24)\quad n/(N(0)\exp(gt)) = X\{k_2/(k_2 + g + r) - (k_2/(k_2 + g + r) - n(0)/(N(0)\ X\ \exp[-(k_2 + g + r)\ t])\}.$$

This solution gives a modified exponential between $n/N(0)$ $\exp(gt)$ and t, rising toward an asymptotic limit of $Xk_2/(k_2 + g + r)$.

e. More realistic extensions of these models can be realized by assuming that for some adopters a correct perception of the new product is attained through contact with prior adopters; for other adopters a correct perception is attained from other sources of information. Since the factors determining the value of k_1 and k_2 overlap, it may be difficult in practice to separate these terms statistically. But we have included these combined models since each part represents conceptually a different and/or mixed marketing strategy. The models described above are special cases of these in which some parameters are assumed _a priori_ to be zero. If we assume that the market is fixed with no entry or exit of adopters or non-adopters, then the following equation represents the process:

$$(25)\qquad n' = X\{ck_1 n(1 - n/XN) + k_2(N - n/X)\}\quad .$$

The solution to (25) is given by,

$$(26)\qquad n/N = (1/2ck_1)\,\frac{2Xck_1 + 2k_2\lambda\exp[-(cXk_1 + k_2)t]}{1 - \lambda\exp[-(cXk_1 + k_2)t]}$$

where λ is a constant of integration.

If we allow for entry and exit then the following equation represents the process:

$$(27)\quad n' = X\{ck_1 n(1 - \frac{n}{XN(0)\ \exp(gt)}) + k_2(N(0)\exp(gt) - n/X) - rn/X\}$$

The solution to this equation is:

(28)

$$\frac{n}{(N(0)\ \exp(gt))} = X\left\{\frac{ck_1X-k_2-g-r+\sqrt{y}+\left(\frac{N(0)}{ck_1X}\right)\lambda\exp(-t\sqrt{y})(ck_1-k_2-g-r-\sqrt{y})}{2ck\ X+2\ \lambda\exp(-t\sqrt{y})}\right\}$$

where $y = 4\ k_2ck_1X + (ck_1X-k_2-g-r)^2$ and λ is a constant of integration.

3. <u>A Modest Improvement and Discussion in Terms of the Theory</u>

Together these models represent a modest improvement over previously presented diffusion models. They integrate ideas which have been anticipated, but not yet joined in a diffusion model. The ideas are the following: The models recognize explicitly that the difference in social structure which determine the value of the contact rate, c, also affect the rate of diffusion -- when contact between adopters and non-adopters influences correct perception of a new product. No other model has done this. The models allow for the possibility that the two basic media which determine perception of a new product are operative simultaneously. The assumption that only one of these media is operative is probably wrong in most cases. Making this assumption, when it is wrong, leads to overstating the effect of the medium included. Haines [27] used a learning model which implied a differential equation equivalent to the one which represents the process when both media are operative; but as far as we know no one has used a diffusion model which combines these. Our models consistently assume that not all potential adopters who have zero differential evaluation will adopt. The assumption that all will adopt is probably wrong for most products. Griliches avoided this latter assumption in his hybrid corn study [26]; and Haines' learning model leads to a differential equation which allows for the possibility that not all who gain a correct perception will adopt. Three of the models we presented allow for entry and exit of potential adopters and non-adopters. It is important to consider the effects of exit in order to understand the early states of the process. One other writer, Ozga [42] incorporated these into his otherwise simpler models.

The advances represented by these models are quite modest compared with the inadequacies of prior models. The limitations of these advances are indicated here: The models' distinction between the effect of the communication structure, c, and the effectiveness of information provided by this structure is not meaningful unless some way can be found to measure c or k_1 separately. It is not clear when it is necessary to use the more general forms of models last presented or when one of the simpler forms suffices. The models are deterministic; but stochastic models may be necessary for handling at least the early stages of the diffusion process. The models' assumptions that the effectiveness of information is constant when attaining correct perceptions of new products may be oversimplified. Understanding these changes may be important for using the model, especially for planning in the early stages of diffusion. To use the models of Table 2 we need more comprehensive models in which the parameters of these models become dependent variables subject to the influence of the decision variables at the disposal of the marketing manager. We do not have such models. The dependent variables of the model are the number or proportion of adopters. Sellers are interested directly in sales. The transformation between the two is not trivial.

It is clearly important to recognize that differences in effective contact rates, ck_1, among markets are due to differences in communication structure, c, as well as to differences in the effectiveness of information, k_1. Sellers can affect the latter, but not the former. The two parameters are probably dependent and may change over time. The models in this paper assume c and k_1 are constant. The marketing manager thus has only a caveat with respect to comparing the effects of different markets, and not a strong tool for formulating such strategies.

To use the theory of diffusion as an aid in new product introduction, it is necessary to know in advance, or at least very early, which model of diffusion is appropriate for the product-market situation in which the theory is to be used. This knowledge is necessary for determining marketing strategy. The theory developed in the previous section offers only rough guidelines for answering this question. Haines' paper contains some suggestive data ([27], pp. 653-654). Haines traced the sales increase pattern of a new consumer non-durable in 33 regions. He fitted equations derivable from equations (17) and (25) for each region. In a majority of regions the terms corresponding to k_1 and X are significant at 0.05. Regions in which this term was significant tended to be those in which competing similar products had been introduced before the one studied. This prior existence of similar products may have reduced the uncertainty and risk of adopting the new product sufficiently for a substantial proportion of potential adopters to buy the product on the basis of non-contact information. Haines' data are no more than suggestive, however, because he measured sales rather than adoptions. Where there are competing products, there is no obvious transformation between them.

The assumption that the increase in the number of adopters is exactly as given in the models in each time period is probably wrong even when the models represent the form of the increase correctly. Many essentially random and minor factors affect the contact rate between adopters and non-adopters: For example, the effectiveness of information in creating correct perceptions of the new product; and the rate at which non-adopters and adopters enter and leave the market. The best we can expect is that the effects of most of these are independent of the basic structure of communication and the decision variables at the disposal of the marketing managers.

The time path given for the number or proportion of adopters by the models we have presented represents at best the expected value of the time path. In the early stages of the diffusion process the expected value of the number of adopters may be positive, but small, while the actual value may be zero. If the process depends upon adopter · non-adopter contacts to produce correct perceptions of a product, the process may stop, unless some fresh adoptions can be attained, even though the time path of expected value of the number of adopters eventually reaches a high value. The reason that deterministic models have been shown in past studies to fit diffusion models fairly well may be that only "successful" diffusions have been considered. Those that failed during the crucial early stage because of random variations bringing the number of adopters to zero have not been included in the studies using econometric procedures.

Kendall [31] has developed a probabilistic model of the spread of infectious disease. The model offers some insight into the problem here: Suppose that, except for I initial adopters which are attained by direct persuasion from the seller, all adoptions result from contact between adopters and non-adopters. Suppose that as before ck_1 is the effective contact rate and r is the rate at which adopters leave the market. If $r>ck_1$ the number of buyers at time t will follow a simple birth and death process which will go to extinction. If $r<ck_1$ then the time path of the number of adopters will behave as though there were a game with two outcomes. Outcome A is a birth and death process going to extinction.

Outcome B is the deterministic system represented by equation (19) in which g is taken as zero. The probability of outcome A is $(r/ck_1)^I$ and the probability of outcome B is $1 - (r/ck_1)^I$ ([31], p. 157). In the world of Kendall's model, some new products would be highly successful, others would not ever really get going, very few would have an intermediate status. If the effective contact rate were constant, if non-contact sources for attaining correct perceptions of a new product were neglectable and if sellers secured some initial adoptions directly and then allowed diffusion to take its course, Kendall's model would be directly useful. None of these is likely to be true, however. We need a model in which the effective contact between adopters and non-adopters, a model in which sellers are permitted a strategy of gradually adding to the number of adopters attained directly. We do not have a solution to such a model.

The models as written incorporate these assumptions: That the effective contact rate and the effectiveness of non-contact information in creating correct perceptions of the new product are constant. This is possible. There are marketing strategies that would lead to this result. It is unlikely, however, that these strategies would involve constant marketing effort. We do not have a model which relates marketing effort to the values of the effective contact rate and the effectiveness of non-contact information; but the theory previously suggested implies that a constant effort would lead to an increase in the values of these variables. For the simpler models, no great mathematical problem is involved in incorporating the assumption that these variables increase. Even in the more complex models, as long as the effectiveness of contact and non-contact information increase at the same rate, and removal from the market is neglectable, the differential equations which represent the processes are separable and therefore soluble. The problem faced by a marketing manager seeking to use such a model is that he does not know which rate of increase, what form of increase and what relationship between this increase in the effectiveness of contact/non-contact information and his decision variables to posit. Even if he knew the eventual value or average values for these parameters, k_1 and k_2, he would not know the values at the early stages when the question of whether the process will die or not is crucial.

The models presented contain as parameters the proportion of potential adopters attaining a correct perception of the product who adopt, and the effectiveness of information in creating correct perceptions of the new product. In order to use these models, more comprehensive models must be designed to contain these parameters as dependent variables, when the independent variables constitute the decision variables at the disposal of the marketing manager. Steps toward such models have been made in two directions. A theoretical framework for models of the adoption process has been constructed by Nicosia ([41], Chapter 6). Nicosia's framework does not contain explicit elements relating to information flow through contacts between adopters and potential adopters. If it were modified in this direction this framework would lead to the construction of the kinds of models that are needed. The other start is the empirical work by Mansfield [38], Griliches [26], and Haines [27] in which they attempt to explain the parameters of the diffusion process by regressing the values of these parameters for diffusions of different innovations (Mansfield) or for the same innovation in different markets (Griliches and Haines) on various determinants which they considered potentially important.

Diffusion models give the time path of growth for the number of adopters of a new product. When the new product has no close substitutes, translating this into a corresponding time path for sales may be fairly straightforward. One might assume that there is an average amount per adopter which will be bought. Perhaps this amount will be less for recent adopters than for old adopters, or perhaps it will remain less for late adopters than for early adopters. Neither of these should be too troublesome if some estimate of the level around which these differ can be made. When the new product has close substitutes, the translation of adoptions into sales is not easy. An adopter may switch from one of these substitutes to another without settling on any, or he may decide to buy one more than another. For frequently purchased products it may be possible to consider stochastic models of consumer purchases (such as Kuehn [33] and Massey [39]) to estimate sales from adoptions.

In order to use these models marketing managers will need estimates of the parameters. This may be very difficult and for two basic reasons: First, some of the parameters appear together as do c and k_1. Unless the values of some of these were known *a priori* or could be held constant, the others could not be estimated. Second, if the new product had close substitutes, it would be necessary to use a simultaneous equations approach.

SUMMARY AND CONCLUSIONS

This paper began by reporting the current interest in diffusion theory as a tool in marketing. We agreed that new product acceptance was a diffusion process and that diffusion theory, therefore, is potentially useful as an aid in marketing. We then presented a theory of the adoption and diffusion processes. An innovation was viewed in terms of changes of activities and the consequences of these changes. The nature of the changes and their consequences are unknown to the potential adopter. This creates risk. Risk leads to differential evaluation. For adoption to occur there usually must be a reduction of differential evaluation. This requires information. The kind and source of information necessary for adoption determines the form of the diffusion process. The effectiveness of information depends upon several factors including the efforts of the seller-change agent, his relation to potential adopters, various aspects of the innovation, the social system of the potential adopters, and the social structure linking them.

We then presented six simple diffusion models. Together the models represent some small improvement over previous work. There are, however, important conceptual and mensurational problems associated with the use of such models. The state of the art in diffusion theory has not advanced sufficiently for a marketing manager to take from it tools which he may "plug in" to his new product introduction techniques. There still remain what Churchman [11] calls "wicked problems."

Some obvious unresolved lines of research in diffusion are: What determines the effectiveness of a communication structure? How, by examining the structure, can a practitioner determine its effectiveness as measured by c in our models? Answers to these questions are necessary if we are to separate the effect of environment from the influence of the marketer. We need to understand the adoption process more fully. What kind of information leads to adoption? Are different kinds necessary at what may be different stages of the process? How does adoption differ among adopters and among products? Answers to these enigmas are necessary in order to determine what kind of diffusion models are relevant between these models and managers' decision variables.

Footnotes

1. The adoption process takes place over time and the early work of Ryan and Gross [47] suggested that an adoption decision may be arbitrarily subdivided into stages for conceptual understanding. That the adoption process could be considered as a sequence of events was also suggested by Pederson [43]. Wilkening [52] first explicitly pointed out that the adoption was a <u>process with stages</u>. Wilkening [53] later listed four stages (awareness, obtaining information, conviction and trial, and adoption). A few years later in 1957 Beal, Rogers, and Bohlen [2] suggested the five stages used in this section. Copp, Sill, and Brown [14] presented evidence which confirms the empirical usefulness of the five stages. In the field of marketing, Lavidge and Steiner [35] proposed a seven-stage process which is similar in outline to the five stages used in this paper. The concept of stages of the adoption process is widely accepted and there was evidence by Ryan and Gross [47] that some information sources were more effective at some stages than others. However, a recent study by Fliegel and Kivlin [23] suggests that the results for adopting hybrid corn may not apply for farm machinery. Most studies indicate a degree of overlap in the effectiveness of different media which provide the information which allows the adopter to reduce his differential evaluation is the one that will be the most effective.

2. Experiments by Bem [4], Brehm and Cohen [8], and Festinger and Carlsmith [21] demonstrate that when a subject thinks

that a behavior is being made in order to receive a reinforcement (which will only obtain if this behavior is made) rather than a "true" belief or attitude, the behavior loses credibility. If an adopter believes that the change agent is encouraging his adoption in order to achieve personal gain, his statements will be discounted as less credible than if he were considered more altruistic.

3. The relative profitability, π_{ij} of the i^{th} innovation in the j^{th} industry is the average rate of return on the investment in adopting the innovation relative to the average overall rate of return on investment in the j^{th} industry.
The relative size S_{ij} of the i^{th} innovation in the j^{th} industry is the average ratio of the cost of adopting the i^{th} innovation to the total assets of the firm j^{th} industry.

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