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SINDI 2:

SIMULATION OF INNOVATION DIFFUSION IN A RURAL COMMUNITY OF BRAZIL

by

Tom W. Carroll

Technical Report 8

Project on the Diffusion of Innovations
in Rural Societies

A research project funded by
the United States Agency for
International Development

Department of Communication

Research Report

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FORWARD

This report has much to commend it to the reader interested in computer simulation of the diffusion of innovations. It is a step forward in a progression of researches on diffusion simulation in that it avoids one of the main shortcomings of these past works: Data were gathered explicitly for the purpose of diffusion simulation from a sample of dairy farmers in Minas Gerais, Brazil. Further, this analysis is relational to the extent that the model pays attention to the dyadic network of interactions involved in the diffusion of innovations. There has been increasing dissatisfaction with much past communication research in which individuals were the units of analysis, as the nature of communication entails a relationship, an interchange. The present study incorporates dyadic data at one point in the analysis.

Also, past diffusion simulation studies have often lacked an adequate method of comparing simulation with reality data, so as to assess the results of the simulation procedures. Tom Carroll pioneers in comparing his simulation results not only with the more usual reality data on the adopter distribution of an innovation, but also with the results of linear regression analysis (which is the most common multivariate type of data-analysis utilized by diffusion researchers).

So for these reasons, and others, the present report constitutes a contribution to our understanding of computer simulation of diffusion. It also illustrates sobering proof that the simulation approach to diffusion (and to other research problems) requires great effort, ability, and resources. It is by no means a simple or easy approach.

But new routes are suggested toward the goal of diffusion researches: The understanding of how new ideas spread and are adopted, the nature of human communication and change. Dr. Carroll himself will be among those researchers who will follow the research maps he describes here.

Everett M. Rogers
Professor of Communication, and
Director, Diffusion Project

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CHAPTER I

INTRODUCTION

The purpose of the research described in this study has been to design a general computer simulation model of the process of the diffusion of innovations and then to apply the model to a particular real-world diffusion system. The impetus for this research grew out of the author's interest in the substantive problem of transferring technology to the developing countries as one aspect of the total modernization process as well as out of his interest in the application of systems analysis and computer simulation to developing formal models of social processes. Clearly, the process by which new ideas and techniques diffuse among members of a social system is central to the overall modernization process of developing countries, particularly in the agricultural sectors. In many cases populations are increasing at a faster rate than is the food supply. For the past several decades diffusion researchers have been studying the process by which ideas and practices diffuse among members of a social system. The motivation behind these efforts has been to formulate better, more rigorous theoretical models which will explain and predict the pattern of real-world diffusion processes. As the models become more refined, they may be used by policy planners and social engineers in order to test alternative strategies for increasing the rate of diffusion of improved practices, particularly in the field of agriculture. For example, a

decision-maker in a federal department of agriculture must decide how to allocate the department's budget. Should he invest more heavily in the mass media as a vehicle for disseminating information about improved agricultural practices or should he invest in training more extension workers? What would be the overall effect of establishing a program of workshops to teach improved agricultural methods to local opinion leaders? Should part of the budget be used for subsidies and credit to help farmers purchase improved seeds, fertilizers, silos, and other agricultural inputs?

This diffusion process can be defined as the communication of an innovation through certain channels among members of a social system over time (Rogers, 1962). More specifically the diffusion process involves "The acceptance, over time, of some specific item -- an idea or practice -- by individuals, groups or other adopting units, linked to specific channels of communication, to a social structure, and to a given system of values, or culture" (Katz et al., 1963).

SINDI 2 is a computer-based model which simulates the diffusion of an innovation through a social system. (SINDI indicates Simulation of INnovation DIffusion.) In the simulation model information and influence flow to potential adopters in the community via the print media (magazines and newspapers), the electronic media (radio and television programs), and word-of-mouth communication with adopters encountered individually and at meetings of community organizations. No provision is made in SINDI 2 for modeling the influence of extension agents or commercial salesmen. The model assumes that each simulated individual manifests a resistance to adopting an innovation which is a function of the individual's demographic and attitudinal characteristics,

the economic characteristics of his enterprise, and the characteristics of the innovation. Each potential adopter is influenced proportionally to his exposure to communications from the various sources. When the cumulative influence on an individual from the various sources exceeds his resistance, he becomes an adopter and thus a source of influence for the remaining potential adopters.

Models of this process may be classified along several dimensions: deterministic versus stochastic, continuous versus discrete, and mathematical versus logical. SINDI 2 is somewhat of a hybrid which incorporates aspects of all of these various types. It is a discrete model in that individuals in the social system are treated as unique entities, each with his own set of attributes. Also, certain discrete events may occur during the processing of the model: individuals may migrate into the community and they may adopt the innovation. On the other hand, what would be unique events of information and influence transfer in the real-world are not treated as unique events by the model, but instead the cumulative influence on an individual resulting from a whole series of such events is treated as a continuous variable which increases monotonically over time. Even though SINDI 2 requires as input data individual probabilities of mass media exposure and of interpersonal interaction as would a stochastic model, it is processed as a deterministic, expected-value model. Furthermore, SINDI 2 has many of the characteristics of a mathematical model because most of the important relationships concerned with the influence processes are expressed as mathematical equations (though implemented as a computer program). However, the behavior of the model, as mentioned above, also depends on the occurrence of certain discrete events; thus, SINDI 2

incorporates logical expressions of the form: If event A occurs, then event B will occur. Finally, SINDI 2 is a computer simulation model because it is a functioning, dynamic model which is processed on a computer so that the changes in the state of the model (and its real-world analogue) may be shown as it moves through time.

SINDI 2 incorporates several important features not often found in other diffusion models. First, since SINDI 2 is processed as a deterministic model, it requires only one run with a given set of parameters to produce an expected-value cumulative adoption curve. Most other diffusion simulation models are stochastic models which require a series of simulation runs with the same set of parameters in order to find the central tendency of the simulated cumulative adoption curve. Second, SINDI 2 simulates the flow of information and influence over the mass media, an aspect of the overall diffusion process not taken into account by many diffusion models, particularly spatial diffusion models. SINDI 2 incorporates an improved technique over its immediate predecessor, SINDI 1,for simulating the effect of the mass media. In SINDI 2 an individual is influenced by a particular mass medium channel proportionally to his probability of exposure to that channel and to the quantity of innovation information carried by that channel. Third, SINDI 2 makes provision for mapping the communication network in order to simulate the flow of inter-personal influence through the social structure. This network is expressed in terms of a series of sociometric dyads characterized by a frequency of interaction and the credibility of the person named in the eyes of the namer. Fourth, SINDI 2 keeps account of the relative contribution of the various channels to the overall diffusion process.

Fifth, an important aspect of this study is that field research was conducted for the primary purpose of gathering data which could be used to design the model and provide data inputs to it. In the case of other models the data inputs have been provided by secondary analysis of empirical data which had not been gathered for purposes of simulation. Sixth, in the application of SINDI 2 to a real-world diffusion system, a method of multiple-partial correlation was utilized in order to predict for each individual his resistance to adopting innovation X. Several diffusion researchers who have included the concept of a resistance factor in their simulation models have not been very explicit about the methods to be used in assigning values to these individual resistance factors other than saying that in the aggregate, the resistance should approximate the normal distribution. Seventh, since it is the author's feeling that much social science theory of the future will be stated in a language compatible to the computer, SINDI 2 was formulated as a well-annotated FORTRAN program in which the main theoretical relationships were distilled into the main program of the simulation model The input/output functions of the computer program, the statistical analysis of the results, miscellaneous housekeeping tasks were relegated to supporting subroutines. The FORTRAN program was written in USA Standard FORTRAN to facilitate its use and modification by other researchers. Finally, the operation of SINDI 2 is such that the various empirical constants in the model are evaluated by fitting the model to empirical data much in the same way that the coefficients of a linear regression equation are calculated by the criterion of the least squares fit. In the case of SINDI 2, the simulated curve is fitted to the real-world cumulative adoption curve

so as both to produce the best fit according to the Kolmogorov-Smirnov two-sample test for goodness-of-fit and to produce the highest correlation between the individual simulated adoption times and the empirical adoption times. Many other diffusion models have not explicitly taken into account the fact that most scientific models incorporate empirical parameters which must be evaluated by fitting the model to real-world data.

SINDI 2 was applied to the diffusion of two dairy innovations among 88 dairy farmers in a rural community in Brazil. At the macro level, the empirical parameters were adjusted so the simulated cumulative adoption curve achieved the best possible fit with the empirical cumulative adoption curve. The fit was reasonably good according to the standards of the Kolmogorov-Smirnov two-sample test.

SINDI 2 performed about as well in predicting individual adoption times as the linear regression model of innovation diffusion. The general linear regression model with six attitudinal and economic variables and four communication variables explained about 48 percent of the variance in empirical adoption times. In the case of silo diffusion, SINDI 2 explained approximately 48 percent of the variance in the empirical adoption times. One would have hoped that SINDI 2 would have performed better than the general linear regression model, because SINDI 2 modeled the flow of influence through the interpersonal communication network, an aspect of the overall diffusion process not modeled by the linear regression model.

When SINDI 2 was applied to the diffusion of forage grass plots using the same empirical tuning parameters as were found for the case of silo diffusion, the simulated output explained 26 percent of the variance

in the empirical data. The linear regression model with seven independent variables accounted for 21 percent of the variance. In the case of forage grass plot diffusion the absolute predictive ability of SINDI 2 declined as compared to the predictive ability of SINDI 2 in the case of silo diffusion. However, part of the decline probably resulted from the poorer quality of the empirical data on the diffusion of forage grass plots. Even though the predictive ability of SINDI 2 declined in the case of forage grass plot diffusion, nevertheless, SINDI 2 performed somewhat better than the linear regression model in predicting the individual adoption times of forage grass plots.

Now we shall turn to a detailed discussion of various formal models of the diffusion process which have been formulated by diffusion researchers.

A Review of Diffusion Models

To explain the important factors which influence the course of social diffusion processes, diffusion researchers have developed many different types of models. These include verbal and descriptive models, linear regression and other statistical models, gaming models, mathematical models, and computer simulation models.[1] It should be emphasized for the discussion which follows that the distinction among mathematical models, computer simulation models, and even statistical models, is a matter of degree. Some specific models contain elements of all three types.

---

[1]The Diffusion Documents Center of the Department of Communication at Michigan State University contains over 1300 empirical and theoretical studies from 20 different disciplines (Rogers, 1967, 1968). Most of these studies either present verbal models or summarize findings based on the statistical analyses of empirical data.

Verbal models

In a verbal model, the researcher's primary objective is to abstract and describe qualitatively the important entities, variables, relationships, and interactions in some social process. Anthropologists have had a long-standing interest in the process of cultural diffusion and thus have been among the early contributors to developing verbal models of the diffusion process. Linton (1936, pp. 324-46) discussed some generalizations about the diffusion process which emerged from the field research of the early anthropologists. It is interesting to note that his generalization, "other things being equal, elements of culture will be taken up first by societies which are close to their points of origin and later by societies which are more remote or which have less direct contacts" (p. 328), is equivalent to Hagerstrand's assumption (1953) that geographical distance between adopting units is a major determinant in any spatial diffusion process. Barnett (1953) developed in great detail a verbal model of the psychological process of innovation and the subsequent diffusion of the innovation through a social system. La Piere (1965) adopted Barnett's model as the basis for a general model of social change.

Lionberger (1960), Katz (1963), Rogers (1962), and Rogers with Shoemaker (forthcoming) developed general verbal models which were based on the findings reported by diffusion researchers, particularly sociologists, rural sociologists and communication researchers. Many of these findings were derived from statistical analyses of empirical data on various diffusion processes.

Statistical models

Diffusion researchers have used various statistical models to analyze empirical diffusion data. At the simplest level of univariate analysis, researchers have approximated, by the normal curve, the empirical frequency distributions of times at which individuals or other adopting units adopt innovations. The parameters of the normal curve are then used to classify individuals according to their innovativeness -- "the degree to which an individual is relatively earlier in adopting new ideas than other members of his social system" (Rogers, 1962, pp. 19, 160-64).

Diffusion researchers have used bivariate correlation and partial correlation techniques to arrive at many of the generalizations which were summarized in Rogers (1962, pp. 311-15).

Multivariate techniques such as multiple correlation have been used to identify the correlates of innovativeness, or, in other words, to determine which factors cause some individuals to adopt earlier than other individuals. There are several disadvantages with the multiple correlation approach, however. First, the end result of the analysis is simply a listing of the significant variables along with their weightings relative to their importance. Multiple correlation analysis does not tell how the variables are linked together or at what stage or in what way they contribute to the diffusion process. Second, the linear regression model is not supposed to be an analogue to the real-world diffusion process but rather a statistical model of how the variance in a dependent variable can be partitioned among the variances of independent variables. Recently, however, Salcedo (1968) and Mason and Halter (1968) applied critical path analysis and two-stage least squares techniques respectively to determine the causal linkages between independent variables and their effect on

innovation adoption. Nevertheless these models do not lend themselves to the analysis of a diffusion system's response, particularly in the case where certain controllable inputs such as the quantity of innovation messages carried by the mass media or the efforts of an extension agent may change during the course of the diffusion process.

Gaming models

In gaming models human participants play the roles of the key actors in some real-world social process. The game designer from his understanding of the social process devises the "rules of the game". The rules may specify who talks to whom, when communication with other players may take place and the appropriate actions which may be taken. Gaming has been used in some fields as a research tool for studying the evolution of social processes toward a new set of relationships and outcomes which are not immediately obvious to a casual observer. However, the gaming of social diffusion processes has been used mainly as a training device for students who may later be assuming similar roles in the real world or who seek a greater appreciation and understanding of the social processes they are studying. For example, the Department of Communication at Michigan State University has developed a game called "CHANGE AGENT" in which a player assumes the role of an extension worker who is trying to introduce a new practice into a rural community of a developing country. Another game called "ADOPTER" might be developed in which the players assume the roles of potential adopters of some innovation.

Mathematical models

In mathematical models, the variables are linked by a series of formal equations, where the form of the equation (linear, non-linear, differential, etc.) specifies the manner in which the variables are combined. Each equation contains a series of parameters, one for each variable in the equation. Parameters precisely define the degree of the variable's relationship to certain other variables in the equation. To develop a mathematical model of some system is to presuppose a detailed and sophisticated knowledge of the process being modeled. It also presupposes achieving a high level of measurement -- sound interval-level measurement, if not ratio-level measurement.

The ability to express the process in terms of mathematical equations brings to bear the inherent power and logic of mathematics itself which extends the investigator's ability to gain further insight into the processes under study. Once the researcher has formulated a model, he usually is interested in exploring its behavior by solving the relationships in his model for the dependent variables which interest him but which are embedded in the model's structure. The investigator "solves" his model by "untangling" and "breaking out" the dependent variables in the model's equations so that he can observe their "behavior." Where possible, an investigator usually will try to apply analytic techniques which allow the dependent variable(s) to be expressed as explicit functions of the parameters and independent variables. Examples of analytic techniques include the use of matrix algebra, the method of simultaneous equation differential and integral calculus, and the use of geometric, Fourier and Laplace transforms to analyze linear, dynamic systems.

However, in many cases, a closed-form, analytic solution is not possible and other methods of analyzing the behavior of the model must be utilized. One such technique often applied to dynamic models is simulation. Simulation as a technique for analyzing model behavior will be discussed in the next section.

Griliches (1957) fitted the logistic curve to data on the cumulative percentage of total corn acreage planted with hybrid seed in each of thirty-one states in the United States. Griliches was less concerned with the underlying theoretical model of the real-world diffusion process and more interested in finding a suitable mathematical expression having parameters which summarized the essential features of the aggregate diffusion process. He chose the logistic over the cumulative normal because the logistic was "simpler to fit and in our context easier to interpret." He noted: "In this work the growth curves serve as a summary device, perhaps somewhat more sophisticated than a simple average, but which should be treated in the same manner." His analysis was based on three summary parameters derived from the logistic curve he used:

> The lag in the development of adaptable hybrids for particular areas and the lag in the entry of seed producers into these areas (differences in origins [measured as the date when the S-curve passed through the 10 percent value]) are explained on the basis of varying profitability of entry, "profitability" being a function of market density, and innovation and marketing cost. Differences in the long-run equilibrium use of hybrid corn (ceilings) and in the rates of approach to that equilibrium (slopes) are explained, at least in part, by differences in the profitability of the shift from open pollinated to hybrid varieties in different parts of the country.

He concluded that the characteristics of the diffusion process can be explained in large part by economic variables. Griliches admitted that

his analysis did not purport to present a complete model of the process of technological change. For example, he was not interested in explaining such microdynamics of the diffusion process as the flow of information and influence among individual adopting units within a given area. Also, because of the unavailability of data, the analysis did not take into account the effect on the rate of acceptance from the advertising activities of the extension agencies and private seed companies.

Coleman, Katz and Menzel (1966), unlike Griliches, were interested in the microdynamics of the diffusion process. They fitted data on the diffusion of the acceptance of a new drug among physicians to different mathematical models. A major concern in their research was how the network of personal relationships among the physicians affected the process of the diffusion of a new drug. Sociometric data were obtained on the advice and information network, the discussion network, and the friendship network. Analyzing the diffusion data in conjunction with the data on these interpersonal networks, the authors found that there were two distinct processes at work.

Diffusion among doctors integrated into the social structure (defined as doctors receiving two or more sociometric choices) occurred as a snowball or contagion process which started out slowly, spread rapidly among integrated doctors, and then tapered off sharply as most of the doctors became adopters. Thus, this process is characterized by the commonly observed S-curve of adoption. Coleman (1964) demonstrated that this process can be represented mathematically by the following differential equation:

$$\frac{dx}{dt} = kx(N - x)$$

where x = number of people who have adopted at any point in time,
t = time,
k = diffusion constant of proportionality, and
N = population size.

This mathematical model, which might be referred to as the "social interaction model," simply says that the rate of adoption (number of people adopting per unit of time) is proportional to the number (x) who have already adopted the innovation and to the number ($N - x$) who have yet to adopt. Integration of the above curve results in the logistic growth curve, the same curve used by Griliches in his analysis.

Coleman, Katz and Menzel found another type of process operating among doctors who, relatively isolated from other doctors in their communities, recieved few or no sociometric choices. The cumulative adoption curve for the individual process, as it was called, rose most steeply at the beginning and then gradually tapered off. The mathematical model underlying the individual process is expressed in the form of a differential equation as:

$$\frac{dx}{dt} = k(N - x)$$

This model, which might be referred to as the "constant source model," says in effect that the rate of adoption is proportional only to the number ($N - x$) remaining in the population who have yet to adopt. The basic assumption of the model is that the population is exposed to a constant source of influence such as detailmen or mass media. Integration of this differential equation yields a logarithmic curve which rises as a damped exponential to the asymptote N.

Since the logistic curve fitted reasonably well the adoption data for the integrated doctors and the constant source curve fitted reasonably well the data of the more isolated, Coleman (1964, p. 44)

concluded:

> The integrated doctors were in a social position to learn about the drug and be persuaded to use it quickly, while the isolated doctors, out of contact with their fellows, had to depend upon the advertising and drug salesmen to be persuaded to use the drug.

Several points may be made about the use of these two mathematical models in these cases. First, it is unlikely that either case is purely a snowball process or an individual process. Undoubtedly, some of the integrated doctors, particularly the earlier adopters, were influenced to begin to prescribe the drug by information in the mass media and by drug detailmen. It is also likely that some of the isolated doctors were influenced by other doctors. Many of these activities may have taken place early in the process; Coleman did not include the first 15 percent of the adopters in the curve fitting. Second, even though Coleman was using mathematical models to learn something about the underlying social process behind the observed data, in neither case does the model assume any differentiation in the attributes of the individual adopting units. Essentially then these mathematical models are used to explain aggregate behavior, not individual behavior. In fact, Coleman, Katz and Menzel (1966, p. 103) rejected the theory that normally distributed degrees of individual receptivity play a role in the diffusion process. Third, both models have an empirical constant which must be evaluated by fitting the model to the real-world data. This is a fact of life not uncommon to most all scientific models of real-world phenomena but sometimes overlooked by social scientists who have developed simulation models.

Dodd and Peirce (1967) also discussed the uses of three basic mathematical models in diffusion research: the normal curve, the

waning exponential curve (equivalent to the constant source model above), and the logistic curve (also noted above). However, their discussion of the rationale behind the normal curve did not mention the notion of normally distributed degrees of receptivity to an innovation. Their "well-controlled" laboratory experiment of message diffusion among 78 people who were instructed to interact "at will" was too well-controlled to be a meaningful example of a social diffusion process. "At will" was probably interpreted by the subjects to mean randomly. The experiment could equally as well have been performed by automatons or simulated on a computer using a random number generator.

Most of the simpler mathematical models lack many of the structural biases that are present in any real-world system. For example, the logistic growth model makes the assumption that interaction between individuals in a system is completely random. This assumption violates research findings which show that friendships form between people of similar background and interests. As a result, efforts have been made to formulate more complicated models that reflect some of the structural and processual biases of most social systems.

Coleman (1964) developed deterministic models for two types of "incomplete social structures." The first model approximated a social structure of very tight-knit cliques within which there was complete communication between clique members (in his example, only two) but between which there was no communication. When one member of the clique adopted the trait, then the probability that the other member would become an adopter increased. All individuals were exposed to communication from a constant source. Coleman applied this model to the case of diffusion of a drug among doctors who share offices with a

partner. Coleman extended this model somewhat by incorporating a third transition rate which was proportional to the total number of adopters in the system. This extension of the model, in effect, incorporated a clique bias into a combined constant source and social communication model. The model was expressed as a pair of nonlinear differential equations which could not be solved analytically. Coleman performed a parametric analysis on the equations using a digital computer; or, in other words, he performed a series of "simulation experiments" in order to perform a "sensitivity check" on the various parameters in the differential equations.

In his second model, Coleman assumed a social system composed of partially interpenetrating groups or cliques. The members of these groups associated among themselves more within the groups than between the groups. This model was also expressed as two differential equations which could not be solved analytically. Coleman qualitatively explored the effects of variations in the degree of interpenetration between the two groups and the variations in ratio of group sizes on the "trajectory" of the diffusion process. The trajectory is the curve which gives the cumulative number of adopters in one group as a function of the cumulative number of adopters in the other group rather than as a function of time. Even though Coleman's models were based on the assumption of probabilistic interactions between members in a social system, the models themselves were deterministic.

Bartholomew (1967) preferred to develop stochastic models of the diffusion process even though he recognized that many of his stochastic models could not be solved analytically. Whether or not a person hears the information about a new item depends on first the probability of his coming into contact with the source or a spreader, and second the probability

of the information being transmitted when contact is established. Thus, Bartholomew concluded that such processes could only be described stochastically. He utilized a deterministic, "approximate" analysis only when he could not make headway with an analysis of the stochastically formulated models.

Bartholomew formulated a stochastic model of a diffusion process in which people learn the information through exposure to a constant source and through interaction. This was the stochastic version of combined constant source and social interaction models discussed by Coleman. Bartholomew pointed out that the solution to the deterministic model was not equal to the solution to the stochastic model but instead lagged the stochastic solution by an amount of time which depended on the total number in the population and the ratio between the constant source parameter and the social interaction parameter.

Bartholomew also described and extended the work of Bailey (1957), Rapaport (1958 with citations to earlier work), and Daley and Kendall (1955) on stochastic models.

Bailey (1957) developed a general epidemic model which extended the simple diffusion model. The simple diffusion model assumes random interaction of "susceptibles" with "infectives" (or "have-nots" with "haves" or "nonknowers" with "knowers" or "ignorants" with "spreaders" depending on the process being modeled). In his general epidemic model Bailey added a third type of individual, the "removal," (or "passive knower") who has acquired the trait but subsequently ceases spreading it. In other words, the assumption was made that infectives are only active for a random period of time after which they become passive. It was also assumed that an infective's cessation of activity is independent

of the degree to which the trait has already diffused throughout the population.

Rapaport (1958 with citations to earlier work) developed a series of biased net models which were extensions of the simple random net model. The simple random net model assumes a spatial distribution of nodes which become interconnected with the passage of time. When a node becomes connected to the system, it can issue one or more edges to other nodes in the time period immediately following and only in that time period. (In Bailey's terminology, all infectives become removals after only one time period.) In a random net model the target nodes are hit by issued edges with equal probability. In a biased net the assumption of equal probability of being hit by an issued edge is dropped in favor of a specified probability for each pair of nodes. The probability depends on the structure of the system.

Rapaport has developed the following biased net models:

Distance bias model: The probability that two nodes become connected is a function of the geographical or social distance between the two nodes.

Island bias model: The nodes are clustered into non-overlapping subsets within which the connection probabilities are random but between which the connection probabilities are non-random.

Overlapping acquaintance circle model: This model is similar to the island-model above except that overlapping subgroups are allowed.

Reflexive or reciprocity bias model: The probability that $c \rightarrow a$ will occur depends on the existence of $a \rightarrow c$ or $a \rightarrow b \rightarrow c$.

Forced field bias model: Connection to certain nodes is more probable because of the attributes associated with these nodes, as for example, high status.

The solutions to biased net models are usually expressed as recursion equations in which the probability of a particular node (x_o)

being connected to the network in time period (t + 1) is a function of the probability of not being connected in any of the previous time periods and a function of the various biases incorporated into the model. A summary of the mathematical formulation, solution, and empirical testing of Rapaport's geographical distance bias model may be found in Brown (1965, pp. 34-37).

Bartholomew (1967) discussed the stochastic model formulated by Daley and Kendall (1965) in which the cessation of spreading by spreaders depends on the extent of diffusion which has already taken place within the system. "If a spreader meets an ignorant, the news is transmitted and the ignorant becomes a spreader. If a spreader meets someone who has previously been informed he ceases to spread the news. Those who have heard but are no longer spreading are called 'stiflers' because, on contact with a spreader, they cause him to cease spreading." In a more complicated version of this simple model a spreader becomes a stifler after k unsuccessful attempts at telling the news. The quantity k either is fixed or is a random variable.

None of the stochastic models discussed thus far takes into account a potential adopter's resistance to accepting the new idea. Thus these models are better applied to the diffusion of information such as rumors, news, and public warnings rather than to the diffusion of innovations where the potential adopter makes a conscious decision to adopt the innovation after first hearing about it.

Brown (1966) extended Rapaport's geographic distance biased net model by including a probaility that a potential adopter will resist adopting an innovation after first hearing about it in a given time period. Brown also included several market factors in his biased net

model such as the distribution policy of the propagators of the innovation and the behavior of potential adopters with respect to shopping in a particular market. He applied his model to the diffusion of television sets in an area of southern Sweden. It was found that the model provided a plausible explanation of the real-world process. Brown also drew attention to the notion of controllable inputs to the diffusion system. In this particular case the inputs most amenable to manipulation were the marketing strategies of the propagators of the innovation. The distinction between controllable inputs and uncontrollable inputs is one that is often emphasized by system analysts. An example of uncontrollable inputs to a diffusion system would be word-of-mouth communication across the boundaries of the diffusion system.

Computer simulation models

Social scientists sometimes use the term computer simulation model to refer to a logical model which is expressed in the form of a series of precise statements, operating rules or programmed instructions which describe how a system operates as it moves through time. However, "computer simulation" actually refers to one particular method of analysis which can be used to explore the behavior of a formal model when the dependent variables of the model cannot be solved for by ordinary mathematical techniques and thus cannot be expressed as closed-form functions of the independent variables. Simulation is used to observe the change in the dependent variables as the system moves through simulated time. Thus simulation can be applied to a wide variety of formal models -- mathematical or logical, discrete or continuous, stochastic or deterministic, to mention some of the major

dimensions along which they may be classified. Naylor et al. (1966, p. 3) emphasized the concept of simulation as a technique of numerical analysis:

> Simulation is a numerical technique for conducting experiments on a digital computer, which involves certain types of mathematical and logical models that describe the behavior of a business or economic system (or some component thereof) over extended periods of real time.

Shubik (as quoted in Naylor et al., p. 2) offered a similar definition:

> A simulation of a system or an organism is the operation of a model or simulator which is a representation of the system or organism. The model is amenable to manipulations which could be impossible, too expensive or impractical to perform on the entity it portrays. The operation of the model can be studied and, from it, properties concerning the behavior of the actual system or its subsystems can be inferred.

Both these definitions emphasize that simulation is one technique for exploring the behavior of a model with the hope of then making inferences about the real-world system. However, characterization of model formulation and its solution as a two-stage process is not meant to imply that the stages are independent of each other. In most cases the investigator, while he formulates his model, will keep in mind the method of analysis he intends to employ on the model and the type of "solution" he is seeking. Thus, it is not surprising that a social scientist who formulates a logical model in the form of a computer program (or an algorithm which can be transformed into a computer program) and who expects to have his model processed on the computer refers to his model as a "computer simulation model."

Nevertheless, social scientists sometimes overlook the distinction between the formulation of the model and its "solution." For example, it is sometimes assumed that the only way to analyze a model containing probabilistic relationships is by a Monte Carlo simulation which

utilizes a random number generator to process the probabilistic relationships in the model. However, for cases in which there is a large number of entities and events, the model sometimes can be solved deterministically to yield an expected-value solution. A familiar example of an expected-value analysis of a probabilistic system is the use of mortality tables to calculate life insurance premiums. In the same manner we shall see that, although SINDI 2 requires exposure probabilities as input data, the model is processed deterministically to yield an expected-value cumulative adoption curve.

The earliest research on the simulation of diffusion processes was carried out by Torsten Hägerstrand (1953), a Swedish geographer. Being a geographer, he was primarily interested in understanding and explaining the spatial-temporal diffusion of innovations within a geographical region. His basic model was governed by a set of theoretical statements (or rules) about how the simulated process was to take place (Hägerstrand, 1965):

1. At the outset there is one single adopter of some hypothetical innovation.

2. The innovation is adopted as soon as it is heard of.

3. Information is spread exclusively through private tellings at pair-wise meetings.

4. The tellings take place at constant intervals of time (called generation intervals); then every adopter informs another individual adopter or nonadopter.

5. The destination of every telling is given by the aid of random numbers according to the probabilities of the mean information field.

The "mean information field" is a probability matrix which expressed the probability of communication between any two individuals living in a geographical region as a function of the distance between them. It should be noted that conditional probabilities were used in Hagerstrand's mean information field: given that A communicates with B,

p is the probability that B will live in an area x miles from A. The mean information field said nothing about how frequently A communicated with someone else nor whether in a given communication he passed information about innovation X. Hägerstrand and other geographers have estimated the probabilities in the mean information field by utilizing data on telephone calls between villages, on migration, and even on distances which people travelled to attend a community barbecue (Bowden, 1965).

In an extension of his basic model Hagerstrand modified Rule 2 above to take into account the notion of psychological resistance to adopting an innovation: "Adoption takes place after a specified number of tellings (the threshold), different for different individuals." In the application of this rule, Hägerstrand assumed that resistances varying from one to five tellings were normally distributed in the population and thus he arbitrarily assigned resistances to the simulated individuals in order to reproduce the normal distributions. In his original study (1953) he suggested that resistance should be related to certain characteristics of the adopting units such as, in the case of farmers, to farm size. However, he did not implement this procedure for assigning resistances in any application of his simulation model to real-world diffusion data.

Further extensions of his basic model deal with anisotropies in the model plane. In his basic model he had assumed that the simulated adopting units were distributed uniformly across the model plane. He extended the basic model by allowing the distribution of simulated adopting units to reflect the real-world distribution within a geographic region. Another extension of the basic model made provision

for "barriers to communication along certain cell-boundaries in order to imitate the effect of the lakes and roadless forests that cut up the real area." During the processing of the simulation model these barriers in some cases blocked communications from taking place at all between certain cells and in other cases diminished the frequency of communication.

When the simulated results of various runs of his model were compared with the empirical patterns of spatial diffusion in certain areas of Sweden it appeared that the models had predicted reasonably well spatial diffusion of the selected innovations. Although Hägerstrand made a significant contribution to simulating spatial diffusion processes, there were several problems with his work. First he lacked rigorous tests for goodness-of-fit between the simulated results and the real-world diffusion pattern. Second, it has already been noted that he did not implement a method for assigning resistances to the adopting units in his simulated population. Third, there is no way in the model to relate real-time to the model generation periods except ex post facto comparison of the two time dimensions. In some cases there was a nonlinear relation between the two time dimensions. Fourth, the models had no provision for simulating the role of the mass media in the diffusion process. And finally, the model did not take into account that there are likely to be other factors beside geographical distance which influence the communication probabilities.

Pitts (1963, 1965 and 1967) has programmed variations and extensions of Hagerstrand's models in CDC FORTRAN for Control Data computers. In addition to programming the stochastic models, Pitts also programmed an expected-value, deterministic solution which he called the Omega

pattern. This solution was equivalent to making N runs with a Monte Carlo model where N is a large number (1000 or more). If the results of each one of these unique runs are averaged, then the results of this average will be the expected pattern for a given set of data inputs. Rather than making 1000 runs to achieve the Omega pattern, Pitts developed the Omega Program which calculated the expected number of new knowers in each geographical cell at the end of each simulated time period. Thus the number of tellers in each cell for the next time period is equal to the "whole" number of knowers in that cell. In other words, if a cell has an average of 3.57 knowers at the end of a time period then there would be 3 tellers during the next time period. Thus, the Omega Program produces an expected-value cumulative adoption curve.

Tiedeman and Van Doren (1964) utilized a Hägerstrand-type model to simulate the diffusion of hybrid seed corn in Iowa. Their model incorporated two mean information fields: one field represented the spatial influence of individual adopters while the second field represented the spatial influence of seed stores.

Karlsson (1958) discussed methods for including in diffusion models both the mass media and the effects of social structure on the communication probabilities.

Rainio (1961) formulated a model which simulated the process by which individual members of a small group choose between two opinions or between two behavioral alternatives. Contacts with other group members sometimes weaken and sometimes strengthen an individual's probability of behaving in a certain manner. Unlike most other models, Rainio's model allowed for change in the probabilities of contact

between members depending on previous simulation events. Rainio assumed that both the changes in individual behavior probabilities and the changes in the sociometric interaction probabilities obey the laws of learning as postulated in the Bush-Mosteller "Two Operator" model. Although Rainio did not consider his model to be a diffusion model, nevertheless he did acknowledge the influence of Hägerstrand and Karlsson on his own work. In situations where the two alternative choices were to adopt or not to adopt an innovation, Rainio's model could be classed as a diffusion model.

Deutschmann (1962) developed a Monte Carlo simulation model (Model II) of the diffusion of information in a small Latin American community.[2] Since the geographical area containing the population was assumed to be relatively small, Deutschmann did not include distance between individuals as a variable in the model but instead emphasized the effect of clique structure, opinion leaders, and individuals' preferences for information channels (local face-to-face, external face-to-face, and mass media) on the diffusion process.

SINDI 1 is a computerized version of the original Deutschmann model with modifications (Hanneman et al., 1969 and Hanneman and Carroll, 1969). SINDI 1 is a stochastic (Monte Carlo) model programmed in USA Standard FORTRAN (United States of America Standards Institute, 1966). SINDI 1 incorporates the following assumptions about diffusion within a peasant community:

1. The innovation enters the social system through external

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[2]Deutschmann (1962) developed a simple simulation model (Model I) of how attitudes of individuals in a polarized community change in response to messages carried by the mass media and in encounters with other people in the community.

channels.

2. Individuals within a community can be divided into cliques of highly interacting members, with local word-of-mouth messages flowing more frequently within cliques than between cliques.

3. There is small group of individuals ("tellers") within the community with a high probability of passing information to others after they have received it; all others have a low probability of passing information.

The following parameters are defined as input to SINDI 1: (1) the number of cliques, the number of members in each clique, and the number of potential tellers in each clique; (2) the number of contacts allowed to each external channel source per time period; (3) the number of contacts allowed to a teller once he becomes a knower; (4) the probability of a non-knower becoming a knower through any external channel source; (5) the probability of a member of a clique becoming a knower through contact with a teller from any clique.

Technically, SINDI 1 consists of a main program and five subroutines. The main program handles the monitoring tasks for the simulation: it acts as a "clock" by executing the time-varying DO loops and calling the other subroutines. The first subroutine reads in the parameters and initializes arrays for the beginning of a run and a time period. In the external message subroutine each external channel randomly contacts a specified number of individuals. Associated with each individual (as an input parameter) is an information transfer probability based on his channel orientation (to either a specific external source-channel or to local face-to-face contacts) and the channel source of the message for a particular contact. A randomly generated number between zero and one is compared with the information transfer probability: if the former is less than or equal to the latter,

the person will become a knower; if not, he remains a non-knower. The teller contact subroutine functions like the external message section except that the information transfer probability depends on the individual's clique membership and the clique membership of a contacting teller. The output subroutine prints out a summary of the information transfer events for the simulation. There is also a random number generator which provides random integer subject numbers and random decimal numbers between zero and one based on the extension of Lehmer's rule.

Runs were made with SINDI 1 using input parameters and probabilities derived from a secondary analysis of data collected in a Colombian peasant village by Rogers.[3] There were two external source-channels carrying information about agricultural innovations (for this series of runs, 2,4D weed spray) into the peasant village: the extension agent and the school teacher. The simulated population was created by dividing the 56 peasants in the community into four interacting cliques and one group of 11 isolates on the basis of their answers to the sociometric question: "Have you spoken with another farmer in the last two months about agriculture? With whom?"[4] Nine of these peasants were considered as potential tellers, each of whom would begin telling

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[3]For a discussion of Rogers' research concerning the impact of communication on peasant villages in Colombia see Rogers (1969).

[4]Eleven of the isolates were dropped from the original sample of 67 because they had had no contact with any of the other farmers, the extension agent, nor the school teacher. The remaining 11 isolates were included in the simulated population because they at least had had some contact with either the extension agent or the school teacher.

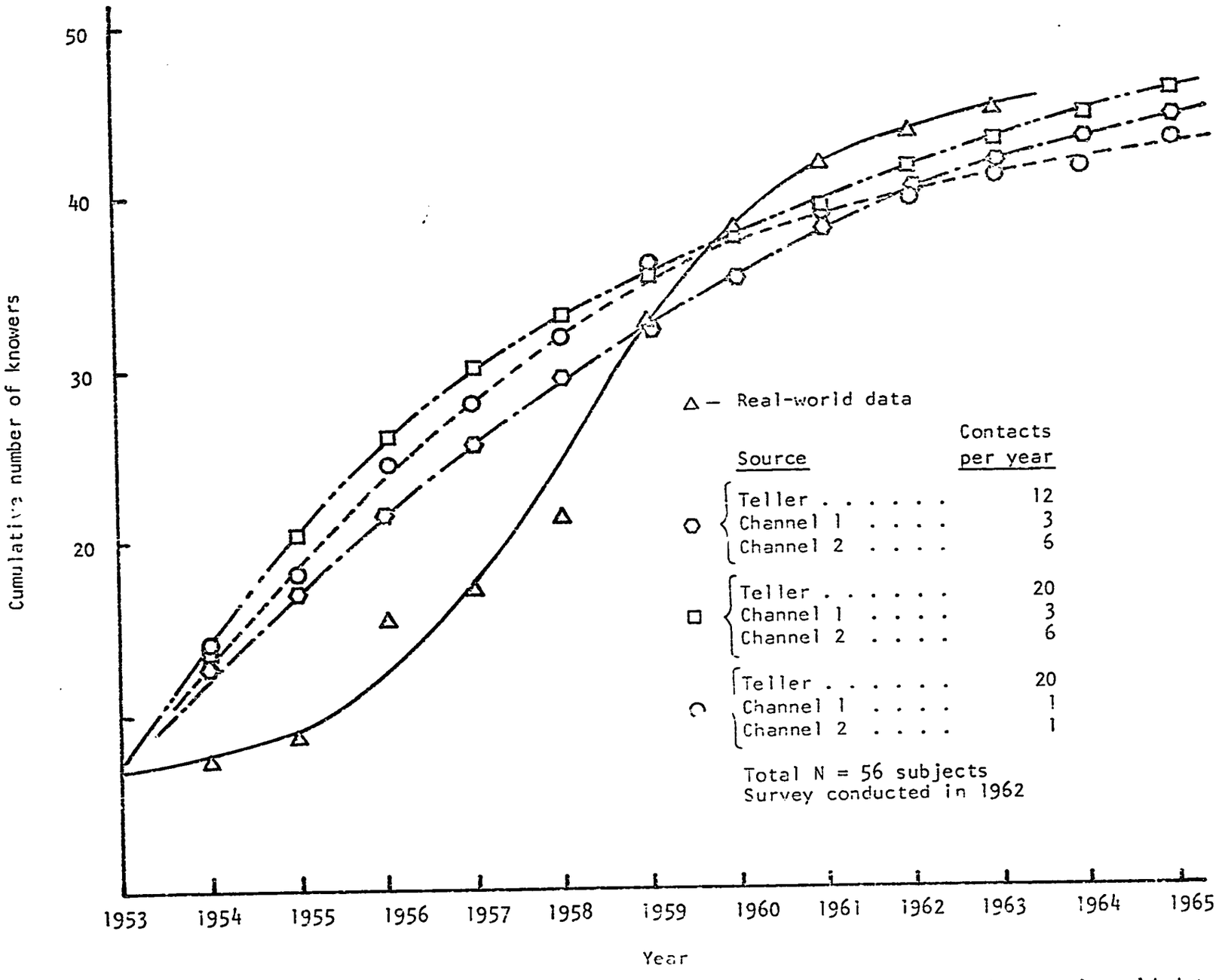

Figure 1.1 SINDI 1: results of three series of simulation runs compared to real-world data.

structural biases were introduced through probability matrices for information transfer given that a contact had been made. The assumption of random contacts is a questionable representation of real-world communication behavior. In fact, the empirical data collected in this community show that contact with external sources is highly nonrandom; some individuals have considerable contact with these sources while many others have no contact. Third, the model only simulated the diffusion of information not adoption. It made the assumption that "tellers" would start disseminating as soon as they became knowers. However, it was unlikely that "tellers" would be active disseminators until they had actually become adopters and were convinced of the worth of the innovation themselves. Fourth, to divide the population into tellers, each with the same degree of influence, and non-tellers might have been too severe a distortion in the representation of the real-world "opinion leadership." It is likely that opinion leadership is a continuous variable which varies in degree from those individuals who have wide influence throughout the community down through those who may influence one or two close friends to those who have little or no influence on anybody.

In the last of a series of three unpublished papers, Deutschmann (1962) described the design of Model III which would simulate the flow of both information and influence leading to the adoption of an innovation by members of a community. Model III was built on the concepts incorporated in Model I, a simulation of attitude change in a polarized community, and in Model II, a simulation of information diffusion in a small community. In Model III it was assumed that each individual has a "general orientation to change,"

which becomes the basis for the individual's specific attitude score toward innovation X. An individual attitude was modified during the course of the simulation to messages about X from external source-channels and from members of the social system. The operating rules for Model III specified that there is a ceiling effect for an attitude score and that "an attitude not operated upon by a message for n time periods will regress toward the neutral point."

Deutschmann assumed that the information carried by the external source-channels about innovation X is all favorable and that the attitudes of individuals who receive the information become more favorable toward X; in other words, one unit is added to their attitude score for each message received. As in Model II the external source-channels contact random individuals. Each individual's channel orientation determines the probability of receiving information about innovation X during a contact with a particular source-channel. The only relationship between attributes of individuals which Deutschmann incorporated in the model specified that external channel orientation was positively related to general favorability to change. Instead of assuming that the population was dichotomized into tellers and nontellers as was the case in Model II, Deutschmann allowed every contact between individuals in the social system to have some influence on the attitudes toward X of each individual in the contact pair. As in Model II, the individuals were randomly matched for each contact. Depending on the combination of adopters, knowers, or non-knowers in the pair and their respective clique attachments, either influence transfer, information transfer, or nothing would happen. In the case of influence transfer between an adopter and a knower or between two knowers,

"both individuals will be affected in the direction indicated by the sum of attitude scores."

Deutschmann's mechanism for simulating adoption was to specify that when an individual's attitude reached a predetermined level of favorability he would become an adopter. At this time a positive increment would be added to his attitude score so that it would be less likely for an individual to oscillate back and forth across the adoption threshold. Setting a disadoption threshold below the adoption threshold also had the same effect.

Deutschmann's Model III was never programmed for the computer and thus never run with real-world data inputs. Consequently there were several ambiguities which were never clarified in the original brief description of the model. For example, what value was to be chosen for the adoption threshold? Was this value to be the same for all individuals? What would be the procedure for determining the general orientation to change for each individual and how would this variable be converted to a specific attitude toward innovation X? An individual's initial attitude toward different innovations is likely to vary depending on the characteristics of the innovations.

Objectives for SINDI 2

We have reviewed various formal diffusion models including mathematical models, logical "computer simulation" models, deterministic models, and stochastic models. The models vary in the amount of microanalytic detail which they include. The constant source model and the logistic growth model are examples of deterministic, mathematical models which model diffusion systems with the least degree

of complexity. The solutions to these two models are readily obtainable and approximately represent the aggregate behavior of many real-world diffusion systems. However, as the mathematical models become more complex in order to take into account the biases of a real-world diffusion system they become more difficult to solve analytically. At a certain threshold of complexity the models become difficult even to formulate mathematically. Coleman (1964, p. 495) noted that "to mirror the full complexity of such structures would require detailed measurement followed by a simulation with the structure mapped onto the memory of a computer."

The following pages describe SINDI 2, a deterministic, logical, computer simulation model of the diffusion process in a social system exposed to mass media messages. The purpose of the research reported below is to develop a reasonably detailed model of the simulation of an innovation. SINDI 2 was designed to incorporate the better features of some of the models already discussed and to utilize empirical data which were collected especially for the purpose of providing inputs into a simulation model.

CHAPTER II

SINDI 2: SIMULATION OF INNOVATION DIFFUSION

The purpose of this chapter is to describe SINDI 2, a computer-based model which simulates the diffusion of an innovation through a social system. The process of the diffusion of the use of silos among the dairy farmers living in a Brazilian rural township was the real-world process used for the development of SINDI 2. Although SINDI 2 was designed to model this specific diffusion system, the model itself is general. Once the model has been validated, it could be used to simulate diffusion in other systems with similar characteristics. Testing the general model in other situations is a way of further validating it.

Alternative Formulations

Preliminary thinking about the formulation of a diffusion simulation model suggested three different approaches. Each approach hinged on how the model would simulate the innovation decision process -- the decision-making process that each individual goes through from first awareness about an innovation to final adoption or rejection (plus, in many cases, post-decision reinforcement behavior).

The first of these approaches would have been to develop a "black-box decision module" to simulate the process from first awareness to final adoption or rejection. In this approach the model would have

simulated the diffusion of first awareness among individuals through their exposure to the mass media and other individuals of the social system. However, the lag time from first awareness to final adoption would have been incorporated into the model through an empirical technique such as multiple regression, by which the lag time would have been predicted from various demographic, attitudinal, and economic characteristics of the individual. A researcher might adopt this approach if he either did not understand or was not interested in modeling the details of the decision-making process.

A second approach would have been to develop a "cognitive but passive decision module": "cognitive" in the sense that each simulated individual stores in memory the number of innovation messages he has received, but "passive" in the sense that he automatically becomes an adopter after the number of messages he has received exceeds a certain threshold. This approach would have made no attempt to simulate how an individual rationally determines on the basis of economic and other factors whether he will adopt or not. This is the approach suggested by Hagerstrand and Deutschman. However, neither Hagerstrand nor Deutschmann is very clear on how this threshold will be determined for various individuals.

A third approach might have developed a "cognitive, rational decision module." In this approach each simulated individual not only is aware of the innovation messages impinging on him but also "rationally" processes this information in terms of the constraints of his own situation in order to decide if and when he will adopt. To develop decision modules of this sophistication presupposes a detailed understanding of how various factors interact to affect an individual's

decision. This approach is related to the current work in artificial intelligence.[1]

Each of these approaches has its drawbacks. The first approach, the black box approach, was found to be inadequate because the empirical data, which is discussed later in this report, showed no significant correlation between awareness-to-adoption time and other independent variables. Large measurement error probably accounts for the low correlation. To most people the time of first awareness is not a particularly salient piece of information which can be easily recalled. Even time-of-adoption is often subject to considerable error of recall. The difference between these two measures tends to yield a very unreliable measure. Thus this approach did not prove to be workable.

The cognitive, rational approach was not workable because there was insufficient theory and data to develop a programmable model of innovation decision-making.

SINDI 2: An Overview

SINDI 2 is essentially a communication model of a diffusion system. In the simulation, information and influence flow to the potential adopters in the community via the print media (magazines and newspapers), the electronic media (radio and television programs), and word-of-mouth communication with adopters encountered individually and at meetings of community organizations. No provision has been made in SINDI 2 for interaction with extension agents or commercial salesmen.

The "decision module" for each simulated individual follows the

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[1] See, for example, the work of Newell and Simon (1963) on simulating general problem-solving behavior.

cognitive, passive approach outlined above but also incorporates aspects of the other two approaches. The following assumptions are incorporated into the model:

1. Each simulated individual manifests a resistance to adopting an innovation in the face of influence from his environment. This resistance is a function of the individual's demographic and attitudinal characteristics and the economic characteristics of his enterprise and the characteristics of the innovation.

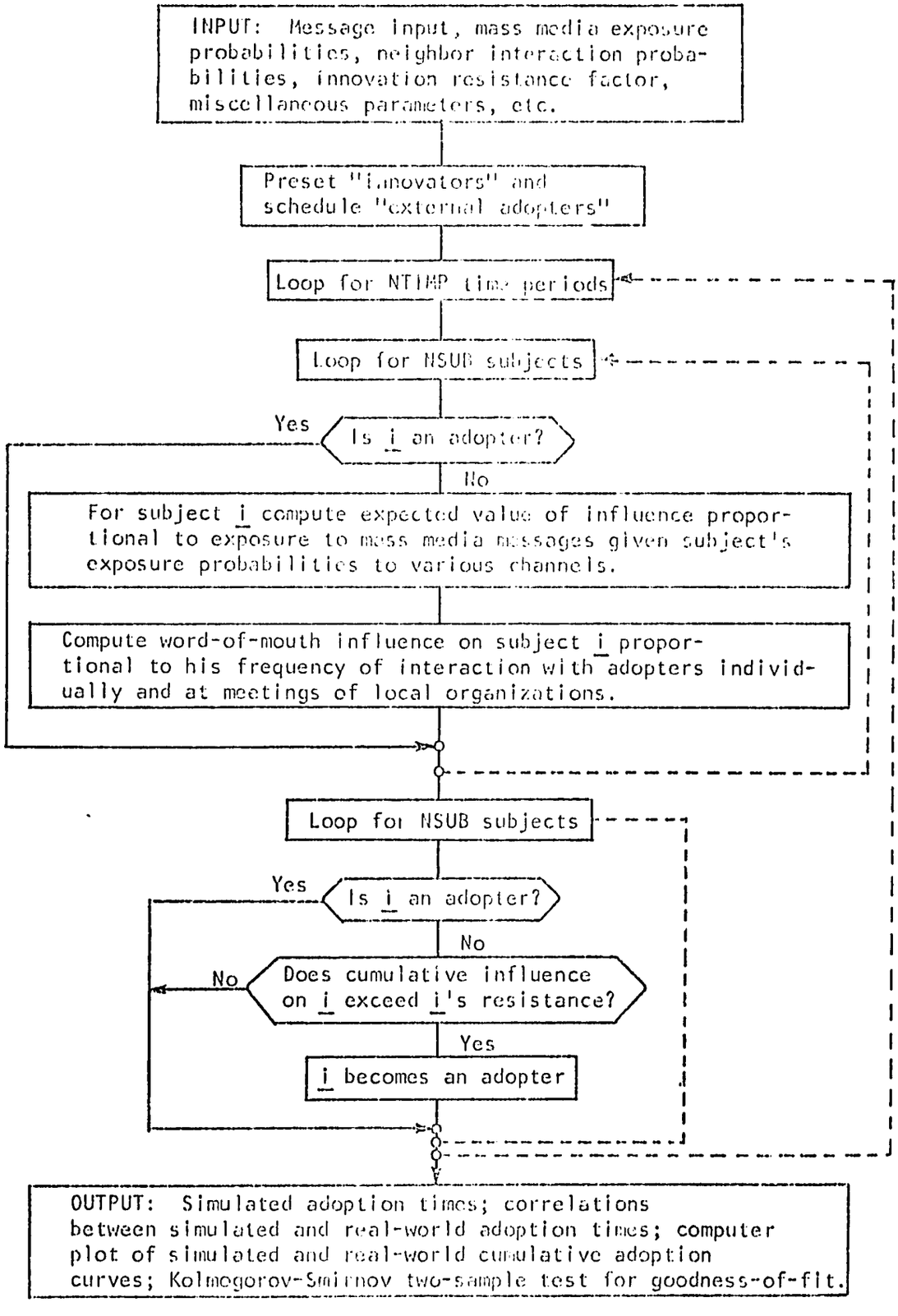
2. Each potential adopter is influenced proportionally to his exposure to innovation information carried in the mass media and to his frequency of interaction with adopters in his community.

3. When the magnitude of an individual's cumulative influence from various sources exceeds the magnitude of his resistance to adoption, he becomes an adopter.

A simplified flow chart for SINDI 2 appears in Figure 2.1. After reading in the input data and parameters required for the simulation, SINDI 2 initializes "innovators" and schedules "external adopters." "Innovators" are those individuals who adopted the innovation prior to the simulation starting time; "external adopters" are those individuals who adopted the innovation somewhere outside the community and then migrated into the community after the simulation starting time. Thus innovators are influential from the very start of the simulation; external adopters become sources of influence within the social system only after they have entered the system.

Besides the run loop, which is not shown on the simplified flow chart, there are three main loops in the simulation program. In the outermost loop of the three, SINDI 2 cycles through a preset number of

Figure 2.1 Flowchart for SINDI 2



time periods. Within each time period there are two loops which cycle through the simulated subjects.

The first of these loops computes the expected value of influence on each subject who has not yet adopted the innovation. This expected value of influence is proportional to each subject's probability of exposure to innovation messages carried by the mass media and to the subject's probability of interaction with adopters encountered individually and at meetings of local community organizations. The mathematical relationships which express the degree of influence for each type of channel follow.

Statements A-69 and A-70 of the FORTRAN program which follows compute the influence effect on individual i from his exposure to innovation messages in magazines and newspapers during the current time period. In mathematical notation, these two FORTRAN statements could be expressed as*:

$$EMAGNW_{(i,itimp)} = CMAGNW \cdot \sum_{jmn=1}^{NMAGNW} PMAGNW_{i,jmn} \cdot MMAGNW_{jmn,itimp}$$

The influence effect from magazines and newspapers on an individual during the current time period is proportional (CMAGNW being the constant of proportionality) to the sum of the expected values of innovation information received from the various magazines and newspapers during the current time period. The expected value of an outcome is defined

*The subscripts which appear in parentheses in the mathematical equations in the text do not appear in the computer program presented in the next section. In the computer program values of a variable along the dimension of the parenthetical subscripts appearing in the text are stored in temporary locations of core memory.

as the probability of an outcome taking place times the value of the outcome. In this case, $PMAGNW_{i,jmn}$ is the probability that individual i reads a particular issue of magazine or newspaper jmn, and $MMAGNW_{jmn,itimp}$ is the quantity of innovation information carried by that particular channel during time period itimp and measured as square inches of print information.

Likewise the expression (contained in statements A-73 and A-74) for influence from innovation information carried on radio and television programs is:

$$ERADTV_{(i,itimp)} = CRADTV \cdot \sum_{jrt=1}^{NRADTV} PRADTV_{i,jrt} \cdot MRADTV_{jrt,itimp}$$

In this case $MRADTV_{jrt,itimp}$, the quantity of innovation information carried by radio or television program jrt during time period itimp, is measured in minutes of time.

Subjects who have not yet adopted may be exposed to word-of-mouth communication under two different types of situations. In one case they may encounter adopters at meetings of local organizations. The influence effect for this case is programmed as statements A-78 and A-79 which are equivalent to the mathematical expression:

$$EMLORG_{(i,itimp)} = CMLORG \cdot \sum_{jlo=1}^{NLORG} PMLORG_{i,jlo} \cdot AMLORG_{jlo,(itimp)}$$

$PMLORG_{i,jlo}$ is the probability that individual i will attend any given meeting of local organization jlo. $AMLORG_{jlo,(itimp)}$ is the average number of times that adopters attend the meetings of local organization jlo during a given time period. The expected value of $AMLORG_{jlo,(itimp)}$

is computed in statements A-56 to A-59 at the beginning of each time period.

Individuals may also interact with other individuals in their circle of discussion partners. Empirically it usually is found that the number of people included in this circle varies from individual to individual. Some individuals have a wider circle of discussion partners than other individuals. Thus, if sociometric influence were computed as being proportional to interaction with adopters, other things being equal, individuals with more discussion partners would be subject to greater absolute sociometric influence from adopters than individuals with only a few discussion partners. For example, an individual interacting with three adopters among ten discussion partners would be influenced more than the individual interacting with two adopters among three discussion partners, even though in the latter case the individual would be aware that a greater percentage of his discussion partners had adopted. Thus, since a straight proportionality to interaction with adopters does not seem to be a completely adequate representation of the interpersonal influence process, a somewhat more complicated expression for sociometric influence is included in the simulation. This expression for ENEHBR (influence Effect from NEIgHBoRs) which is programmed in statements A-83 to A-85, can be expressed mathematically as:

$$ENEHBR_{(i,itimp)} = CNEHBR \cdot \sum_{ij=ija}^{ijz} ADOPTR_{j,(itimp)} + CINERT \cdot (ADOPTR_{j,(itimp)} - 1.0) \cdot SOCINF_{ij}$$

$$0 \leq CINERT \leq 1$$

where $j = NAMED_{ij}$

and $SOCINF_{ij}$ is calculated in A-34 as

$$SOCINF_{ij} = CREDIB_{ij} \cdot (DRDAYS \cdot PDISC_{ij})^{CINFLU} \qquad 0 \leq CINFLU \leq 1$$

The first equation sums the influence contribution made by each discussion partner named by an individual. When $ADOPTR_{j,(itimp)} = 1.0$, then the expression in brackets takes on a value of 1.0. When $ADOPTR_{j,(itimp)} = 0.0$ (i.e. individual j is not yet an adopter), then the expression in brackets is equal to -CINERT. (CINERT is a simulation parameter which the researcher sets to some value between zero and one.) Thus, included in this expression for sociometric influence is an "inertial" negative influence from interaction with nonadopters. The nonadopters are programmed to be passive in the sense that their negative influence only reduces the positive influence from adopters during that time period but can never add a negative influence to the total cumulative sociometric influence. In other words statement A-88 of the FORTRAN program insures that CNEHBR for a given time period will never be less than zero, and hence the cumulative sum of sociometric influence, SNEHBR, will never be less than zero.

The equation for $SOCINF_{ij}$ computes a relative sociometric influence effect as a function of the discussion partner's credibility and the raw frequency of contact during a time period raised to the exponential power of CINFLU (a simulation parameter between zero and one). When CINFLU equals 1.0 then $SOCINF_{ij}$ is exactly proportional to the raw frequency of contact with the discussion partner ij. In other words a discussion partner whom a subject sees every day has 90 times the influence of a discussion partner whom he sees once every three months. When CINFLU equals 0.0 the $SOCINF_{ij}$ is independent of the raw frequency

of contact and only depends on the credibility rating of the person named. In this case, a discussion partner whom a subject sees every day during the time period has the same influence as the discussion partner he sees only once or twice during the time period. The actual value of CINFLU probably lies somewhere between zero and one.

The second subject loop at the end of each time period checks to see if the cumulative influence on a subject exceeds his resistance to adoption. If it does, then the subject becomes an adopter and can begin influencing others in subsequent time periods.

After having cycled through all the time periods the program then outputs the results. A separate output analysis program[2] produces a computer plot of the simulated and empirical cumulative adoption curves and performs the Kolmogorov-Smirnov two-sample test.

SINDI 2: The Computer Model

The most explicit statement of the diffusion simulation model is the computer program itself. The main program of SINDI 2 and a list of definitions for variables, arrays, and indices included in the program follow below. Not listed in this report are the various subroutines which read in the input data and simulation parameters, compute simple statistics, output the results, and perform other "housekeeping" tasks.

SINDI 2's method for mapping the sociometric communication network is somewhat different from the usual methods. In many studies of sociometric relationships the data is summarized in the form of a square matrix in which the rows are associated with the persons

---

[2]Adapted from a program package implemented at the Michigan State University Computer Laboratory by Morris (1967).

being named. However, this approach is wasteful of the computer's core memory because most of the entries are usually zero, indicating that there is no interaction between the two individuals. In SINDI 2 the communication structure is mapped as a set of sociometric dyads. Each dyad represents a one-way communication link and is characterized by the following fixed attributes: the identification number of the person who is the namer, the identification number of the person who is named, the frequency of discussion about work-related matters, and the credibility of the person named in the eyes of the namer. To calculate sociometric influence SINDI 2 cycles through this set of sociometric dyads. A list processing language was not used to keep track of the circle of discussion partners associated with each individual because the communication structure was assumed to remain unchanged during the duration of a simulation run.

SINDI 2 is programmed in USA Standard FORTRAN (United States of America Standards Institute, 1966). The SINDI 2 source deck for the main program and the subroutines contains approximately 450 FORTRAN statements excluding comment cards. When this program was compiled on the CONTROL DATA 3600 Computer at the Michigan State University Computer Laboratory, it required approximately 8200 words of core memory for the instructions contained in the binary object program and supporting system routines and for the input/output buffer areas. An additional 10,200 words of core memory were allocated to store in COMMON blocks the various variables, arrays, and indices used in simulating diffusion in a community of 100 individuals and 800 specified sociometric relationships. When SINDI 2 was applied to a community of 88 simulated individuals interacting in a communication

network comprised of 324 sociometric dyads, each series of runs required 25 seconds of execution time to load the program and read in the data. Each run within a series required approximately 4 seconds of execution time. When run on the CONTROL DATA 6500 Computer, SINDI 2 required an additional 1000 words of core memory for buffer areas, 5 seconds of central processor time to load the program and read in the data for each series of runs, and slightly more than 1 second to execute each run.

The output analysis program which on a second pass through the computer produced the cumulative distribution plots on the line printer and performed the Kolmogorov-Smirnov two-sample test, required somewhat less core memory than did SINDI 2 and only a few additional seconds of execution time.

```
      PROGRAM SINDI2                                                    A   1
C     SIMULATION OF INNOVATION DIFFUSION
C     VERSION 2.4C (11/12/68)
C     USA STANDARD FORTRAN PROGRAM BY T.V.CARROLL
C
      REAL MMAGNW,MRADTV,MLORG                                          A   2
      COMMON /A01/ LUNI,LUNO,LUNP,LUNT,KLY(4),DESCRP(13)                A   3
      COMMON /A02/ IRUN,NRUN,IRUNA,IRUNZ                                A   4
      COMMON /A03/ ITIMP,NTIMP,RTIME,RTIMEA,DRTIME,DRDAYS               A   5
      COMMON /A04/ I,NSUB,IJ,NDYAD,IJA,IJZ                              A   6
      COMMON /A05/ PMAGNW(100,15),MMAGNW(15,50),JMN,NMAGNW              A   7
      COMMON /A06/ PRADTV(100,10),MRADTV(10,50),JRT,NRADTV              A   8
      COMMON /A07/ AMLORG(5),PMLORG(100,5),MLORG(5,50),JLO,NLORG        A   9
      COMMON /A08/ IDEXT(100),TENTCM(100),TBEGOP(100),NAMES(100)        A  10
      COMMON /A09/ IDINT(110),IE,IEZ                                    A  11
      COMMON /A10/ NAMER(800),NAMED(800)                                A  12
      COMMON /A11/ PDISC(800),CREDIB(800),SOCINF(800)                   A  13
      COMMON /A12/ SMAGNW(100),SRADTV(100),SMLORG(100),SNEMBR(100)      A  14
      COMMON /A13/ TADDAT(100),REGR(100),RESIST(100)                    A  15
      COMMON /A14/ ADOPTR(100),TADSIM(100),ITAG(100),ISORT(100)         A  16
      COMMON /A15/ CMAGNW,CRADTV,CMLORG,CNEMBR,CINFLU,CINERT            A  17
      COMMON /A16/ REGRMN,REGRSD,RISTMN,RISTSD                          A  18
C
C
C         LOGICAL UNIT ASSIGNMENT AND PARAMETER SETTING
C         ==============================================
C
      LUNI = 60                                                         A  19
      LUNO = 61                                                         A  20
      LUNP = 62                                                         A  21
      LUNT =  1                                                         A  22
      PRSUAP = 2.0                                                      A  23
C
C
C         INPUT -- PARAMETERS AND DATA
C         ============================
C
C              SUBROUTINE INPUTP READS IN BASIC PARAMETERS FOR EACH
C              SIMULATION RUN -- RUN DESCRIPTION, INPUT-OUTPUT CONTROL
C              KEYS, AND REAL TIME AT START OF SIMULATION AND AT DATA
C              COLLECTION.  IT ALSO READS IN THE TOTAL NUMBER OF
C              EACH OF THE FOLLOWING -- SIMULATION RUNS, TIME PERIODS,
C              MAGAZINES AND NEWSPAPERS, RADIO AND TELEVISION PROGRAMS,
C              LOCAL ORGANIZATIONS, INDIVIDUAL SUBJECTS, AND SOCIOMETRIC
C              DYADS.  (SUBROUTINE IDENTIFICATION CODE LETTER = B)
      CALL INPUTP                                                       A  24
C
C              SUBROUTINE INPUTI READS IN EACH SUBJECT*S ENTRY TIME INTO
C              THE COMMUNITY, THE START-UP TIME OF HIS ENTERPRISE, HIS
C              PROBABILITY OF EXPOSURE TO EACH MASS MEDIA CHANNEL, AND
C              HIS PROBABILITY OF ATTENDANCE AT MEETINGS OF EACH LOCAL
C              ORGANIZATION   INPUTI ALSO READS IN THE DATA ON THE
C              SOCIOMETRIC DYADS.  THESE DATA SPECIFY THE IDENTIFICATION
C              NUMBER OF THE NAMER, THE IDENTIFICATION NUMBER OF THE
```

```
C             PERSON NAMED, THE PROBABILITY OF DISCUSSION ABOUT WORK-
C             RELATED MATTERS, AND THE SOURCE CREDIBILITY OF THE PER-
C             SON NAMED AS SEEN BY THE NAMER.     (C)
      CALL INPUTI                                                       A  25
C
C             SUBROUTINE INPUTA READS IN EACH SUBJECT*S EMPIRICAL
C             ADOPTION TIME AND HIS RAW RESISTANCE-TO-INNOVATING
C             FACTOR PREDICTED FROM MULTIPLE REGRESSION.     (D)
      CALL INPUTA                                                       A  26
C
C             SUBROUTINE INPUTM READS IN THE QUANTITY OF INNOVATION
C             INFORMATION CARRIED BY EACH MASS MEDIA CHANNEL AND THE
C             NUMBER OF MEETINGS HELD BY EACH LOCAL ORGANIZATION
C             DURING EACH SIMULATED TIME PERIOD.     (E)
      CALL INPUTM                                                       A  27
C
C
C         SIMULATION RUN LOOP
C         ===================
C
      DO 150  IRUN = IRUNA,IRUNZ                                        A  28
C
C             SUBROUTINE INPUTT READS IN THE SIMULATION TUNING PARAM-
C             METERS.  THESE INCLUDE VALUES FOR (1) THE MEAN AND
C             STANDARD DEVIATION OF THE SUBJECTS* TRANSFORMED
C             RESISTANCE-TO-INNOVATING FACTORS, (2) COMMUNICATION
C             EXPOSURE INFLUENCE PARAMETERS--CMAGNW, CRADTV, CMLORG,
C             CNEHBR -- AND (3) SOCIOMETRIC INTERACTION PARAMETERS--
C             CINFLU AND CINERT.     (F)
      CALL INPUTT                                                       A  29
C
C         VARIABLE INITIALIZATION FOR NEW RUN
C         -----------------------------------
C
C             THE NEXT TWO STATEMENTS LINEARLY TRANSFORM REGR(I), THE
C             RAW RESISTANCE FACTOR PREDICTED FROM MULTIPLE REGRESSION,
C             TO RESIST(I), THE RESISTANCE OF INDIVIDUAL I TO INNO-
C             VATION COMMUNICATIONS RECEIVED DURING THE SIMULATION RUN.
      DO 10  I = 1,NSUB                                                 A  30
   10 RESIST(I) = (RISTSD/REGRSD)*(REGR(I)-(REGRMN-REGRSD))+(RISTMN-    A  31
     . RISTSD)                                                          A  31
C
C             THE NEXT TWO STATEMENTS CALCULATE RELATIVE SOCIOMETRIC
C             INFLUENCE ON INDIVIDUAL I FROM INDIVIDUAL J, ONE OF I*S
C             DISCUSSION PARTNERS, AS A FUNCTION OF J*S CREDIBILITY AND
C             THE RAW NUMBER OF INTERACTIONS PER TIME PERIOD RAISED TO
C             THE POWER OF CINFLU.  CINFLU IS A SIMULATION PARAMETER
C             BETWEEN ZERO AND ONE.
      DO 20  IJ = 1,NDYAD                                               A  33
   20 SOCINF(IJ) = CREDIB(IJ)*(DRDAYS*PDISC(IJ))**CINFLU                A  34
C
```

```
C               INITIALIZE STATE VARIABLES
      DO 30  I = 1,NSUB                                                 A  35
      SRADTV(I) = 0.0                                                   A  36
      SMAGNW(I) = 0.0                                                   A  37
      SMLORG(I) = 0.0                                                   A  38
      SNEIBR(I) = 0.0                                                   A  39
      ADOPTR(I) = 0.0                                                   A  40
      TADSIM(I) = 0.0                                                   A  41
      ITAG(I) = 3                                                       A  42
C                     TAG INNOVATORS
      IF (TADDAT(I).LE.RTIMEA)  ITAG(I) = 1                             A  43
C                     TAG EXTERNAL ADOPTERS
      IF ((TADDAT(I).LE.TENTCM(I)).AND.(TENTCM(I).GT.RTIMEA)) ITAG(I)=2 A  44
C                     FOR INNOVATORS AND EXTERNAL ADOPTERS, SET SIMULATED
C                     ADOPTION TIME EQUAL TO EMPIRICAL ADOPTION TIME.
      IF (ITAG(I).LE.2)  TADSIM(I) = TADDAT(I)                          A  45
   30 CONTINUE                                                          A  46
C
C               SUBROUTINE ORDER(1) SORTS INNOVATORS INTO CHRONOLOGICAL
C               ORDER ACCORDING TO THEIR EMPIRICAL ADOPTION TIMES.
C               ORDERI(2) ORDERS OTHER SUBJECTS AS THEY BECOME ADOPTERS.
C               (H)
      CALL ORDERI (1)                                                   A  47
C
C                     INITIALIZE REAL TIME
      RTIME = RTIMEA-0.5*DRTIME                                         A  48
C
C
C         TIME PERIOD LOOP
C         ================
C
      DO 130 ITIMP = 1,NTIMP                                            A  49
      RTIME = RTIME+DRTIME                                              A  50
C
      DO 40  I = 1,NSUB                                                 A  51
      IF (ADOPTR(I).EQ.1.0)  GO TO 40                                   A  52
C                    ACTIVATE INNOVATORS AND EXTERNAL ADOPTERS AS
C                    ADOPTERS IN THE COMMUNITY WHEN SIMULATED REAL TIME
C                    EXCEEDS THE TIME THEY ENTERED THE COMMUNITY.
      IF ((ITAG(I).LE.2).AND.(RTIME GE.TENTCM(I)))  ADOPTR(I) = 1.0     A  53
      IF ((ITAG(I).EQ.2).AND.(ADOPTR(I) EQ.1.0))  CALL ORDERI (2)       A  54
   40 CONTINUE                                                          A  55
C
C               THIS SECTION COMPUTES AT THE BEGINNING OF EACH TIME
C               PERIOD THE AVERAGE NUMBER OF TIMES ADOPTERS ATTEND
C               MEETINGS OF A PARTICULAR LOCAL ORGANIZATION DURING
C               THE TIME PERIOD.
      DO 50  JLO = 1,NLORG                                              A  56
      AMLORG(JLO) = 0.0                                                 A  57
      DO 50  J = 1,NSUB                                                 A  58
   50 AMLORG(JLO) = AMLORG(JLO)+MLORG(JLO,ITIMP)*ADOPTR(J)*PMLORG(J,JLO)A  59
C
```

```
C                    RESET SOCIOMETRIC LOOPING PARAMETERS
      IJA = 0                                                           A  60
      IJZ = 0                                                           A  61
C
C
C         SUBJECT LOOP FOR MESSAGE EXPOSURE
C         =================================
C
      DO 110  I = 1,NSUB                                                A  62
C
C               THE FOLLOWING TWO STATEMENTS ADJUST THE DYAD LOOPING
C               PARAMETERS SO THAT IJA POINTS TO THE DYAD WITH THE FIRST
C               SOCIOMETRIC DISCUSSION PARTNER NAMED BY INDIVIDUAL I AND
C               IJZ POINTS TO THE DYAD WITH THE LAST PARTNER NAMED BY I.
      IJA = IJZ+1                                                       A  63
      IJZ = IJZ+NAMES(I)                                                A  64
C
C               THE NEXT THREE STATEMENTS CAUSE THE PROGRAM TO BYPASS THE
C               MESSAGE EXPOSURE SECTIONS FOR ADOPTERS, NONOPERATORS
C               (INDIVIDUALS WHO HAVE NOT YET SERIOUSLY CONTEMPLATED
C               STARTING AN OPERATION), INNOVATORS AND EXTERNAL ADOPTERS.
      IF (ADOPTR(I).EQ 1.0)  GO TO 110                                  A  65
      IF (RTIME.LT (TBECOP(I)-PRSUAP))  GO TO 110                       A  66
      IF (ITAG(I).LE.2)  GO TO 110                                      A  67
C
C         MASS MEDIA COMMUNICATIONS
C         -------------------------
C
C               THIS SECTION EXPOSES EACH NONADOPTER TO INNOVATION
C               MESSAGES CARRIED BY MAGAZINES AND NEWSPAPERS.
      EMAGNW = 0.0                                                      A  68
      DO 60  JMN = 1,NMAGNW                                             A  69
   60 EMAGNW = EMAGNW+CMAGNW*PMAGNW(I,JMN)*MMAGNW(JMN,ITIMP)            A  70
      SMAGNW(I) = SMAGNW(I)+EMAGNW                                      A  71
C
C               THIS SECTION EXPOSES EACH NONADOPTER TO INNOVATION
C               MESSAGES CARRIED ON RADIO AND TELEVISION PROGRAMS.
      ERADTV = 0.0                                                      A  72
      DO 70  JRT = 1,NRADTV                                             A  73
   70 ERADTV = ERADTV+CRADTV*PRADTV(I,JRT)*MRADTV(JRT,ITIMP)            A  74
      SRADTV(I) = SRADTV(I)+ERADTV                                      A  75
C
C                    EACH SUBJECT WHO HAS NOT YET ENTERED THE COMMUNITY
C                    AND HAS NOT YET ADOPTED MAY BE EXPOSED TO MESSAGES
C                    IN THE MASS MEDIA BUT MAY NOT INTERACT WITH OTHERS
C                    IN THE COMMUNITY UNTIL HE HIMSELF HAS MIGRATED INTO
C                    THE COMMUNITY.
      IF (RTIME.LT.TENTCM(I))  GO TO 110                                A  76
C
```

```
C         WORD-OF-MOUTH COMMUNICATIONS
C         ----------------------------
C
C              THIS SECTION EXPOSES EACH NONADOPTER TO INFLUENCE FROM
C              ADOPTERS AT MEETINGS OF LOCAL ORGANIZATIONS.
      EMLORG = 0.0                                                      A  77
      DO 80  JLO = 1,NLORG                                              A  78
   80 EMLORG = EMLORG+CMLORG*PMLORG(I,JLO)*AMLORG(JLO)                  A  79
      SMLORG(I) = SMLORG(I)+EMLORG                                      A  80
C
C              THIS SECTION EXPOSES EACH NONADOPTER TO INFLUENCE FROM
C              ADOPTERS IN HIS CIRCLE OF DISCUSSION PARTNERS.  EACH
C              NONADOPTER IS ALSO EXPOSED TO NEGATIVE INFLUENCE FROM
C              DISCUSSION PARTNERS WHO HAVE NOT YET ADOPTED.
      ENEHBR = 0.0                                                      A  81
      IF (NAMES(I).EQ.0)  GO TO 100                                     A  82
      DO 90  IJ = IJA,IJZ                                               A  83
      J = NAMED(IJ)                                                     A  84
      ENEHBR = ENEHBR+CNEHBR*(ADOPTR(J)+CINERT*(ADOPTR(J)-1.0))*        A  85
     .  SOCINF(IJ)                                                      A  86
   90 CONTINUE                                                          A  87
      IF (ENEHBR.LT.0.0)  ENEHBR = 0.0                                  A  88
  100 CONTINUE                                                          A  89
      SNEHBR(I) = SNEHBR(I)+ENEHBR                                      A  90
C
C                   END SUBJECT EXPOSURE LOOP
  110 CONTINUE                                                          A  91
C
C
C         ADOPTER UPDATE SECTION
C         ======================
C
C              THIS SECTION CHECKS TO SEE IF THE TOTAL INFLUENCE FROM
C              VARIOUS SOURCES ON EACH NONADOPTER EXCEEDS HIS RESISTANCE
C              TO INNOVATING   IF SO, THE INDIVIDUAL BECOMES AN
C              ADOPTER.
      DO 120  I = 1,NSUB                                                A  92
      IF ((ADOPTR(I).EQ.1.0).OR (ITAG(I) LE.2))  GO TO 120              A  93
      SINFLU = SMAGNW(I)+SRADIV(I)+SMLORG(I)+SNEHBR(I)                  A  94
      IF ((SINFLU.LT.RESIST(I)) OR.(RTIME LT.TBEGOP(I)).OR.(RTIME.LT.   A  95
     .  TENTCM(I)))  GO TO 120                                          A  96
      ADOPTR(I) = 1.0                                                   A  97
      TADSIM(I) = RTIME                                                 A  98
      CALL ORDERI (2)                                                   A  99
  120 CONTINUE                                                          A 100
C
C                   END TIME PERIOD LOOP
  130 CONTINUE                                                          A 101
C
C
```

```
C         SUMMARY AND OUTPUT
C         ==================
C
C              THIS SECTION TAGS ALL INDIVIDUALS WHO HAVE NOT ADOPTED
C              BY THE END OF THE SIMULATION RUN.  IT ARBITRARILY SETS
C              THEIR SIMULATED ADOPTION TIME EQUAL TO THE REAL
C              TIME AT THE NEXT TIME PERIOD AFTER THE FINAL SIMULATED
C              TIME PERIOD.
C
      RTIME = RTIME+DRTIME                                              A 102
      DO 140  I = 1,NSUB                                                A 103
      IF (TADSIM(I).GT.0.0)  GO TO 140                                  A 104
      TADSIM(I) = RTIME                                                 A 105
      ITAG(I) = 4                                                       A 106
      CALL ORDERI (2)                                                   A 107
  140 CONTINUE                                                          A 108
C
C              SUBROUTINE OUTPUT PRINTS OUT THE SIMULATION RESULTS.
C              THESE INCLUDE -- (1) MEANS AND STANDARD DEVIATIONS FOR
C              SIMULATED AND EMPIRICAL ADOPTION TIMES, (2) CORRELATIONS
C              BETWEEN SIMULATED ADOPTION TIMES, EMPIRICAL ADOPTION
C              TIMES, AND RESISTANCE FACTORS PREDICTED FROM MULTIPLE
C              REGRESSION, (3) RELATIVE PROPORTION OF INFLUENCE FROM THE
C              VARIOUS INFLUENTIAL SOURCES, (4) SIMULATED ADOPTION TIMES
C              IN CHRONOLOGICAL ORDER FOR EACH INDIVIDUAL PLUS SUMMARY
C              OF SOURCES OF INFLUENCE ON EACH INDIVIDUAL, AND (5)
C              SIMULATED ADOPTION TIMES AND MISCELLANEOUS OTHER
C              DATA FOR EACH INDIVIDUAL.  THE LAST SET OF RESULTS (5)
C              CAN BE OUTPUT ON A SCRATCH UNIT AND/OR PUNCH UNIT
C              TO FACILITATE FURTHER ANALYSIS OF THE RESULTS SUCH AS
C              THE KOLMOGOROV-SMIRNOV TWO-SAMPLE TEST AND COMPUTER
C              PLOTTING OF THE CUMULATIVE ADOPTION CURVES.     (G)
      CALL OUTPUT                                                       A 109
C
C                   END RUN LOOP
  150 CONTINUE                                                          A 110
C
C                   END SIMULATION
      END                                                               A 111


          SUBROUTINE DEFINE
C
C  ADOPTR  (I)  DESIGNATES WHETHER INDIVIDUAL I IS AN ADOPTER.  (NSUB)
C          = 1.0 IF HE IS AN ADOPTER,
C          = 0.0 IF HE IS A NONADOPTER.
C
C  AMLORG  (JLO)  THE AVERAGE NUMBER OF TIMES THAT ADOPTERS ATTEND THE
C          MEETING OF LOCAL ORGANIZATION JLO DURING THE CURRENT TIME
C          PERIOD.  (NLORG)
C
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```
C  CINERT   SIMULATION PARAMETER USED IN THE EXPRESSION FOR ENEHBR TO
C           SPECIFY THE DEGREE OF NEGATIVE INFLUENCE FROM NONADOPTERS.
C
C  CINFLU   SIMULATION PARAMETER BETWEEN ZERO AND ONE WHICH IS USED AS AN
C           EXPONENT FOR THE RAW FREQUENCY OF INTERACTION IN THE CALCU-
C           LATION OF SOCIOMETRIC INFLUENCE, SOCINF(IJ).
C
C  CMAGNW   CONSTANT OF PROPORTIONALITY IN THE RELATIONSHIP WHICH
C           SPECIFIES THE INFLUENCE EFFECT (EMAGNW) ON AN INDIVIDUAL
C           RESULTING FROM HIS EXPOSURE TO INNOVATION INFORMATION CARRIED
C           IN MAGAZINES AND NEWSPAPERS.
C
C  CMLORG   CONSTANT OF PROPORTIONALITY IN THE RELATIONSHIP WHICH
C           SPECIFIES THE INFLUENCE EFFECT (EMLORG) ON AN INDIVIDUAL
C           RESULTING FROM HIS INTERACTION WITH ADOPTERS ENCOUNTERED AT
C           MEETINGS OF LOCAL ORGANIZATIONS.
C
C  CNEHBR   CONSTANT OF PROPORTIONALITY WHICH SPECIFIES THE INFLUENCE
C           EFFECT (ENEHBR) ON AN INDIVIDUAL RESULTING FROM HIS
C           INTERACTION WITH ADOPTERS AND NONADOPTERS IN PAIRWISE
C           COMMUNICATION SITUATIONS.
C
C  CRADTV   CONSTANT OF PROPORTIONALITY WHICH SPECIFIES THE INFLUENCE
C           EFFECT (ERADTV) ON AN INDIVIDUAL RESULTING FROM HIS EXPOSURE
C           TO INNOVATION INFORMATION CARRIED ON RADIO AND TELEVISION
C           PROGRAMS.
C
C  CREDIB   (IJ)  CREDIBILITY OF NAMED (IJ) AS SEEN BY NAMER (IJ) IN
C           MATTERS RELATED TO HIS WORK ENTERPRISE FOR SOCIOMETRIC DYAD
C           IJ.  (NDYAD)  RANGE -- 0.0 TO 1.0.
C
C  DESCRP   (1-13)  THIRTEEN-WORD ARRAY FOR STORING AN ALPHANUMERIC
C           DESCRIPTION.
C
C  DRDAYS   NUMBER OF DAYS PER TIME PERIOD.
C
C  DRTIME   REAL TIME DURATION OF ONE SIMULATION TIME PERIOD.
C           USUAL DIMENSION -- YEARS.
C
C  EMAGNW   INFLUENCE EFFECT ON AN INDIVIDUAL RESULTING FROM HIS EXPOSURE
C           TO INNOVATION MESSAGES CARRIED BY MAGAZINES AND NEWSPAPERS
C           ISSUED DURING CURRENT TIME PERIOD.
C
C  EMLORG   INFLUENCE EFFECT ON AN INDIVIDUAL RESULTING FROM HIS
C           INTERATION WITH ADOPTERS AT MEETINGS OF LOCAL ORGANIZATIONS
C           DURING CURRENT TIME PERIOD.
C
C  ENEHBR   INFLUENCE EFFECT ON AN INDIVIDUAL RESULTING FROM HIS
C           INTERACTION WITH ADOPTERS AND NONADOPTERS (AS DETERMINED BY
C           THE INDIVIDUAL*S LIST OF SOCIOMETRIC CHOICES) ENCOUNTERED IN
C           PAIRWISE COMMUNICATION SITUATIONS DURING THE CURRENT TIME
C           PERIOD.
C
```

```
C  ERADTV  INFLUENCE EFFECT ON AN INDIVIDUAL RESULTING FROM HIS
C          EXPOSURE TO INNOVATION MESSAGES CARRIED BY RADIO AND
C          TELEVISION PROGRAMS DURING CURRENT TIME PERIOD.
C
C  I       INDEX SPECIFYING A PARTICULAR INDIVIDUAL SUBJECT BY HIS
C          INTERNAL CODE NUMBER.  (I = 1,NSUB)
C
C  ICODE   AN INTEGER VARIABLE WHICH IS CHECKED BY THE PROGRAM TO
C          DETERMINE IF IT CONTAINS THE TWO-CHARACTER ALPHANUMBERIC CODE
C          *D *.
C
C  IDEXT   (I)  IDENTIFICATION CODE NUMBER EXTERNAL TO SIMULATION FOR
C          INDIVIDUAL I (E.G. A QUESTIONNAIRE CODE NUMBER).  (NSUB)
C
C  IDINT   (IE)  IDENTIFICATION CODE NUMBER INTERNAL TO THE SIMULATION
C          FOR INDIVIDUAL IE.  (IEZ)
C
C  IE      INDEX INDIRECTLY SPECIFYING AN INDIVIDUAL SUBJECT BY HIS
C          EXTERNAL CODE NUMBER.  DEFINED AS  IDEXT(I)-IDEXT(1)+1.
C          (IE = 1,IEZ)
C
C  IEZ     COMPUTED UPPER LIMIT FOR INDEX IE.  DEFINED AS IDEXT(NSUB)-
C          IDEXT(1)+1.
C
C  IJ      INDEX SPECIFYING A PARTICULAR SOCIOMETRIC DYAD.  (IJ = 1,NDYAD)
C          OR (IJ = IJA,IJZ)
C
C  IJA     COMPUTED BEGINNING VALUE FOR INDEX IJ WHEN THE PROGRAM LOOPS
C          THROUGH ONE INDIVIDUAL*S LIST OF SOCIOMETRIC CHOICES.
C
C  IJZ     COMPUTED FINAL VALUE FOR INDEX IJ WHEN THE PROGRAM LOOPS
C          THROUGH ONE INDIVIDUAL*S LIST OF SOCIOMETRIC CHOICES.
C
C  IRUN    INDEX SPECIFYING THE SEQUENCE NUMBER OF THE CURRENT RUN OF
C          THE SERIES.  (IRUN = IRUNA,IRUNZ)
C
C  IRUNA   INTEGER SEQUENCE NUMBER OF THE FIRST RUN OF A SERIES OF
C          SIMULATION RUNS.
C
C  IRUNZ   INTEGER SEQUENCE NUMBER OF THE LAST RUN OF A SERIES OF
C          SINUMATION RUNS.
C
C  IS      INDEX FOR ARRAY ISORT.  (IS = 1,NSUB)
C
C  ISORT   (IS)  AN ARRAY IN WHICH SUBJECT INTERNAL CODE NUMBERS ARE
C          STORED CHRONOLOGICALLY ACCORDING TO THE SUBJECT*S SIMULATED
C          ADOPTION TIME.  (NSUB)
C
```

```
C  ITAG     (I)  TAG WHICH DENOTES HOW SIMULATED ADOPTION TIME WAS
C           ASSIGNED TO INDIVIDUAL I.  (NSUB)
C           = 1 IF SET EQUAL TO EMPIRICAL ADOPTION TIME IN THE CASE OF
C               INNOVATORS WHO ADOPTED BEFORE THE STARTING TIME OF THE
C               SIMULATION
C           = 2 IF SET EQUAL TO EMPIRICAL ADOPTION TIME IN THE CASE OF
C               EXTERNAL ADOPTERS WHO ADOPTED BEFORE ENTERING THE
C               COMMUNITY.
C           = 3 IF DETERMINED BY SIMULATION.
C           = 4 IF SET EQUAL TO REAL TIME CORRESPONDING TO ITIMP = NTIMP+1
C               IN THE CASE OF SUBJECTS WHO HAD NOT ADOPTED BY THE END OF
C               THE SIMULATION RUN.
C
C  ITIMP    INDEX SPECIFYING CURRENT TIME PERIOD OF SIMULATION RUN.
C           (ITIMP = 1,NTIMP)
C
C  J        INDEX SPECIFYING THE INTERNAL CODE NUMBER OF AN INDIVIDUAL
C           WHEN HE ACTS IN THE ROLE OF AN INFLUENCER.  (J = 1,NSUB)
C
C  JMN      INDEX SPECIFYING A PARTICULAR MAGAZINE OR NEWSPAPER.
C           (JMN = 1,NMAGNW)
C
C  JLO      INDEX SPECIFYING A PARTICULAR LOCAL ORGANIZATION.
C           (JLO = 1,NLORG)
C
C  JRT      INDEX SPECIFYING A PARTICULAR RADIO OR TELEVISION PROGRAM.
C           (JRT = 1,NRADTV)
C
C  KEY      (1-4)  INPUT-OUTPUT KEYS WHICH CONTROL (1) COMPLETE PRINTOUT
C           OF INPUT DATA, (2) COMPLETE PRINTOUT OF RESULTS, (3) BINARY
C           OUTPUT ON LOGICAL UNIT 1, AND (4) OUTPUT ON PUNCH UNIT.
C           = 1 IF DESIRED,
C           = 0 IF NOT DESIRED.
C
C  LUN1     LOGICAL UNIT NO  1 USED AS A SCRATCH UNIT FOR OUTPUTING
C           RESULTS IN FLOATING POINT BINARY FORMAT.
C
C  LUNI     LOGICAL UNIT FOR INPUT.
C
C  LUNO     LOGICAL UNIT FOR PRINT OUTPUT.
C
C  LUNP     LOGICAL UNIT FOR PUNCH OUTPUT.
C
C  MLORG    (JLO,ITIMP)  (TYPE REAL)  MEETINGS OF LOCAL ORGANIZATION JLO
C           DURING TIME PERIOD ITIMP.  DIMENSION -- NUMBER OF MEETINGS
C           PER TIME PERIOD.  (NLORG,NTIMP)
C
C  MMAGNW   (JMN,ITIMP)  (TYPE REAL) INNOVATION MESSAGES IN MAGAZINE OR
C           NEWSPAPER CHANNEL JMN IN TIME PERIOD ITIMP.  DIMENSION --
C           SQUARE INCHES PER TIME PERIOD.  (NMAGNW,NTIMP)
C
C  MRADTV   (JRT,ITIMP)  (TYPE REAL) INNOVATION MESSAGES ON RADIO OR
C           TELEVISION PROGRAM JRT IN TIME PERIOD ITIMP.  DIMENSION --
C           MINUTES PER TIME PERIOD.  (NRADTV,NTIMP)
C
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C  NAMED   (IJ)  REFERS TO INDIVIDUAL J, THE PERSON NAMED IN THE
C          SOCIOMETRIC CHOICE DYAD IJ.  (NDYAD)
C
C  NAMER   (IJ)  REFERS TO INDIVIDUAL I, THE NAMER IN THE SOCIOMETRIC
C          CHOICE DYAD IJ.  (NDYAD)
C
C  NAMES   (I)  NUMBER OF SOCIOMETRIC NAMES GIVEN BY INDIVIDUAL I AS
C          NAMER (IJ).  (NSUB)
C
C  NDYAD   THE TOTAL NUMBER OF SOCIOMETRIC DYADS INCLUDED IN THE
C          SIMULATION.
C
C  NLORG   THE TOTAL NUMBER OF LOCAL ORGANIZATIONS REPRESENTED IN THE
C          SIMULATION.
C
C  NMAGNW  THE TOTAL NUMBER OF MAGAZINES AND NEWSPAPER TITLES
C          REPRESENTED IN THE SIMULATION.
C
C  NRADTV  THE TOTAL NUMBER OF DIFFERENT RADIO AND TELEVISION PROGRAMS
C          (E.G. THE FARMER*S HOUR) REPRESENTED IN THE SIMULATION.
C
C  NRUN    THE TOTAL NUMBER OF SIMULATION RUNS IN CURRENT SERIES.  A RUN IS
C          DEFINED AS ONE CYCLE OF NTIMP TIME PERIODS PLUS ITS OUTPUT.
C
C  NSUB    THE TOTAL NUMBER OF SUBJECTS (OR INDIVIDUALS) IN THE
C          SIMULATED POPULATION
C
C  NTIMP   THE NUMBER OF TIME PERIODS WHICH THE SIMULATION IS ALLOWED TO
C          RUN.
C
C  PDISC   (IJ)  PROBABILITY OF DISCUSSION ABOUT MATTERS RELATED TO WORK
C          OPERATION BETWEEN NAMER(IJ) AND NAMED(IJ) ON ANY GIVEN DAY.
C          (NDYAD)
C
C  PMAGNW  (I,JMN) INDIVIDUAL I*S PROBABILITY OF EXPOSURE TO MAGAZINE
C          OR NEWSPAPER ISSUE JMN.  (NSUB,NMAGNW)
C
C  PMLORG  (I,JLO)  INDIVIDUAL I*S PROBABILITY OF ATTENDANCE AT A
C          MEETING OF LOCAL ORGANIZATION JLO.  (NSUB,NMAGNW)
C
C  PRADTV  (I,JRT)  INDIVIDUAL I*S PROBABILITY OF EXPOSURE TO RADIO OR
C          TELEVISION PROGRAM JRT.  (NSUB,NRADTV)
C
C  PRSUAP  PERSUASION PERIOD PRIOR TO THE TIME WHEN AN INDIVIDUAL BEGINS
C          HIS WORK ENTERPRISE AND DURING WHICH HE CAN BE INFLUENCED BY
C          VARIOUS SOURCES TO ADOPT THE INNOVATION.
C
C  REGR    (I)  MULTIPLE REGRESSION PREDICTION OF INDIVIDUAL I*S
C          RESISTANCE TO ADOPTING AN INNOVATION BASED ON INDIVIDUAL*S
C          DEMOGRAPHIC, ATTITUDINAL AND ECONOMIC CHARACTERISTICS.
C          (SUB)
C
C  REGRM   REGR DISTRIBUTION -- MEAN.
C
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C  REGRSD  REGR DISTRIBUTION -- STANDARD DEVIATION.
C
C  RESIST  (I) INDIVIDUAL I*S RESISTANCE TO INNOVATION ADOPTION.  THE
C          RESIST SCALE, WHICH IS USED IN THE SIMULATION, IS A LINEAR
C          TRANSFORMATION OF THE INPUT REGR SCALE.  (NSUB)
C
C  RISTMN  RESIST DISTRIBUTION -- MEAN.
C
C  RISTSD  RESIST DISTRIBUTION -- STANDARD DEVIATION.
C
C  RTDATA  REAL TIME AT THE POINT OF DATA COLLECTION BY THE USE OF
C          SURVEY QUESTIONNAIRES.
C
C  RTIME   REAL TIME EQUIVALENT OF A SIMULATION TIME PERIOD.
C
C  RTIMEA  REAL TIME AT THE BEGINNING OF THE SIMULATION.
C
C  SINFLU  CUMULATIVE SUM OF MASS MEDIA AND WORD-OF-MOUTH INFLUENCE ON
C          AN INDIVIDUAL.
C
C  SMAGNW  (I) CUMULATIVE SUM OF INFLUENCE EFFECTS ON INDIVIDUAL I
C          THROUGH HIS EXPOSURE TO INNOVATION MESSAGES CARRIED BY
C          MAGAZINES AND NEWSPAPERS ISSUED UP THROUGH THE CURRENT TIME
C          PERIOD.  (NSUB)
C
C  SMLORG  (I) CUMULATIVE SUM OF INFLUENCE EFFECTS ON INDIVIDUAL I
C          FROM HIS INTERACTION WITH INNOVATION ADOPTERS AT MEETINGS OF
C          LOCAL ORGANIZATIONS DURING CURRENT TIME PERIOD.  (NSUB)
C
C  SNEHBR  (I) CUMULATIVE SUM OF INFLUENCE EFFECTS ON INDIVIDUAL I
C          FROM HIS INTERACTION WITH ADOPTERS AND NONADOPTERS IN
C          PAIRWISE MEETINGS (AS DETERMINED BY INDIVIDUAL*S LIST OF
C          SOCIOMETRIC DYADS).  (NSUB)
C
C  SOCINF  (IJ) CALCULATED RELATIVE SOCIOMETRIC INFLUENCE ON INDIVIDUAL
C          I FROM INDIVIDUAL J (ONE OF I*S DISCUSSION PARTNERS) AS A
C          FUNCTION OF J*S CREDIBILITY AND THE RAW NUMBER OF INTERAC-
C          TIONS PER TIME PERIOD RAISED TO THE POWER OF CINFLU.  (NDYAD)
C
C  SRADTV  (I) CUMULATIVE SUM OF INFLUENCE EFFECTS ON INDIVIDUAL I FROM
C          HIS EXPOSURE TO INNOVATION MESSAGES CARRIED BY RADIO AND
C          TELEVISION PROGRAMS UP THROUGH CURRENT TIME PERIOD.  (NSUB)
C
C  TADDAT  (I) TIME OF INNOVATION ADOPTION FOR INDIVIDUAL I ACCORDING
C          TO REAL-WORLD DATA.  (NSUB)
C
C  TADSIM  (I) TIME OF INNOVATION ADOPTION FOR INDIVIDUAL I AS
C          DETERMINED IN THE SIMULATION RUN.  (NSUB)
C
C  TENTCM  (I) REAL TIME INDIVIDUAL I ENTERED COMMUNITY.  (NSUB)
C
C  TBEGOP  (I) REAL TIME INDIVIDUAL I BEGAN HIS WORK OPERATION.  (NSUB)
C
          RETURN
          END
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CHAPTER III

THE DIFFUSION SYSTEM: A DAIRY FARMING COMMUNITY IN MINAS GERAIS, BRAZIL

SINDI 2 was applied to the diffusion of dairy innovations in a farming community located in the southern part of the state of Minas Gerais, Brazil. This chapter describes the community and the process of technological change taking place in its dairy operations. This description provides the "scenario" for the series of formal simulation runs which are summarized in the next chapter.

Field research for this project was conducted while the author worked with the overseas staff of the Brazil Diffusion Project from May to October in 1967.[1] During this time data was collected for the purpose of providing basic information on the diffusion process to be

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[1]The Diffusion Project, a four-year study terminating in 1968, used survey research and multivariate analysis to explore the diffusion of agricultural innovations in Brazil, Nigeria, and India. This project was sponsored by the United States Agency for International Development and was directed by Dr. Everett M. Rogers of the Department of Communication at Michigan State University. Phase I of the project sought to clarify the factors underlying the relative success or failure of programs of directed change at the village level in terms of the characteristics and communication strategies of change agents, the social and communication structures of the villages, and the characteristics of informal leaders in the villages. Phase II concentrated on explaining the variability in innovativeness of individual farmers in developing countries. In Phase III, controlled field experiments were designed to compare the effectiveness of such "treatments" as literacy programs, leadership clinics for informal leaders (so-called "animation" treatments), radiophonic discussion groups, and community newspapers in diffusing information about technological innovations.

used in designing a simulation model, providing empirical values for parameters in the simulation model, and providing data for validating the simulation model.[2]

Site Selection

The original research plan called for 100 interviews to be collected in each of two communities, one community without an agricultural extension agent and the other community with an extension agent. The two communities were to be selected with additional desiderata in mind:

1. The communities should be located in the foodshed of some metropolitan center and at a distance "neither too close nor too far."

2. The communities should have well-defined social boundaries. A community is defined as a group of individuals who interact more frequently among themselves than with people outside the community. The existence of well-defined social boundaries would help to minimize boundary effects caused by individuals included in the simulated population interacting with individuals outside the simulated population.

3. The population of farmers in each community should be relatively stable with little or no migration into or out of the community.

4. The farmers in the communities should be commercial farmers participating in a market economy and not subsistent peasant farmers.

5. At least three or four innovations should have diffused within a relatively short period of time (ideally within about five years) to

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[2]This data collection, particularly the survey of dairy farmers, will be referred to in the text as the Phase 2.8 data collection because it occurred between the Phase 2.5 and the Phase III surveys which were conducted by the staff of the Brazil Diffusion Project. The Phase 2.5 survey was conducted to provide "benchmark" data for Phase III.

a large percentage of the farmers. (The author also had hopes of locating communities in which readily accessible records were kept by a local farm store or the extension agent as to the exact time that the farmers adopted the innovations. However, these hopes were not realized.)

6. The communities should not have contact with short-term foreign extension agents such as Peace Corps Volunteers or technical assistance experts. The author did not want to have to take into account "short-term perturbations" of the diffusion process.

To select the community with an extension agent, a preliminary analysis of the Phase II data was used. During Phase II of the Diffusion Project, the staff had conducted 1307 interviews in 20 communities in July, 1966, one year prior to the Phase 2.8 data collection. The Associação de Crédito e Assistência Rural (ACAR), a semi-autonomous state extension service, had agents working in all 20 communities. On the basis of the desiderata outlined above, the community of Abelhas in the township of Três Corações was selected. For the Phase 2.8 community without an agricultural extension agent, the nearby township of Conceição do Rio Verde was chosen.[3]

Field Research

Most of the research data were collected by means of a formal questionnaire administered to farmers in the two communities. In addition, useful background data were collected by means of informal interviews with opinion leaders and extension agents.

Preliminary field observation indicated that the two most important

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[3]The names of the two townships are pronounced as tras koro'-soi^{n}s and konsa'sau^{n} du 'heu 'verje (following the pronunciation symbols as used in Webster's Third New International Dictionary).

agricultural enterprises in the region were coffee and dairy farming. The decision was made to focus the research on the diffusion of dairy innovations because there seemed to be more such innovations diffusing.

The Phase 2.8 questionnaire was written during late June and early July, 1967. Approximately two-thirds of the questions used were drawn from questionnaires used in Phases I, II and 2.5 and from the questionnaire used by Fonseca (1966). The remaining questions were designed especially for the purposes of simulation, most of these being questions concerning frequencies of exposure to various sources of innovation information.

A pretest version of the Phase 2.8 questionnaire was administered to two dairy farmers by an agronomy student from the agricultural school in Lavras. The author was present during both interviews and despite his limited knowledge of Portuguese was easily able to spot the rough places in the pretest version. Based on this short but effective pretest, the final version of the Phase 2.8 simulation questionnaire was prepared.

Two teams of interviewers, each team consisting of a supervisor and four interviewers, conducted the interviewing in the two communities during the last week of July. Each team had already gained three weeks of interviewing experience with the Phase 2.5 questionnaire; some of the interviewers had participated in the data collection for Phases I and II as well. The interviewers were men and women students from the Federal University of Minas Gerais in Belo Horizonte.

A total of 101 interviews was obtained in Conceição as planned, but for a variety of reasons only 47 interviews were obtained in Três Corações. Four interviews from Conceição were dropped leaving a total of 97. One interview with a female respondent was dropped because the

respondent was an administrator for two farms from which interviews with the owners had also been obtained, and two were dropped because at the time of the interview the respondents did not yet own any cows. Of the 97 remaining interviews from Conceição, 3 were with administrators of the dairy farms in situations where it was not possible to interview the owner--usually because he lived elsewhere most of the time. In Três Corações one interview was dropped because the respondent did not yet own any dairy cows; thus, an N of 46 was left.

During August the data from the questionnaires were coded and punched onto IBM cards which were shipped back to Michigan State University for later analysis.

In September the author returned to the research site in order to obtain more background information on the diffusion process. An effort was also made to secure tape-recorded "decision protocols" --depth interviews with a few farmers concerning their process of innovation decision-making. It was not possible in the short period of time available to perfect this technique, but it was felt that some useful insights were gained which could not have been realized from the questionnaires alone.[4]

Selection of the Diffusion System

After making a preliminary analysis of the data, the author decided to focus on developing a simulation model of innovation diffusion among the dairy farmers in Conceição do Rio Verde. The decision to limit the

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[4]For a discussion of the tape-recorded interviews as a field technique, see Bucher, Fritz, and Quarantelli (1956). An example of its application to the study of consumer product decision-making is found in Cox (1967).

application of the simulation model to this community was made for two reasons. First, a complete census of the dairy farmers living in the communities in the township of Três Corações had not been obtained during the field interviewing. A nearly complete census was felt to be necessary in order to simulate the sociometric interaction within the community. Past diffusion research has shown that sociometric interaction is an important channel for the communication of innovation information. Thus Conceição was chosen because a higher percentage of the dairy farmers had been interviewed. Second, it was felt that a reasonable first objective of the modeling effort would be to develop a simulation model of innovation diffusion in a setting with a minimum of outside influences at work. Once the simple model was validated it could be extended to include the different communication strategies that an extension agent might use while working in a community. Thus Conceição, the community without a formal extension agent at work, represented the simpler diffusion system to model.

Therefore, for the remainder of this report, Conceição will be considered the "simulation" community. However, in order to provide a perspective on how this community compares with other farming communities in Minas Gerais, the 97 dairy farmers interviewed in Conceicao will be compared with the 46 dairy farmers interviewed in Três Corações during Phase 2.8[5] and with the 816 dairy farmers and the 491 nondairy farmers interviewed in the 20 Phase II communities.

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[5]Sixty-one farmers had been interviewed in Três Corações during Phase II; of the 46 farmers who were interviewed in Phase 2.8, 31 had already been interviewed in Phase II.

General Community Description

Conceição do Rio Verde (population approximately 9,000) is located toward the center of the triangle formed by São Paulo to the southwest, Rio de Janeiro to the southeast, and Belo Horizonte, the state capital of Minas Gerais, to the north-northeast (see Figure 3.1). The asphalt roads connecting the three major cities had been constructed during the late 1950's and early 1960's. Conceição lies on an asphalt crosslink, completed in 1966, one year prior to data collection, between the Belo Horizonte-São Paulo highway and the Rio-São-Paulo highway. The region surrounding Conceicao comprises probably the richest agricultural region in the state of Minas Gerais. Although Conceição did not yet have any formal extension agencies at work, the dairy farmers living in this region were considered to be quite progressive. The dairy farmers who were interviewed reported relatively high exposure to mass media channels carrying agricultural information as well as a few contacts with extension agents from neighboring townships. Also 5 percent reported attendance at an agricultural school beyond the sixth grade, and 7 percent reported at least some university education. At the time of the interview the old farm cooperative had been disbanded and a new dairy cooperative founded. The new dairy cooperative was in the process of constructing a milk collection center and installing the most modern refrigeration equipment available from São Paulo. The cooperative was planning to distribute its milk and milk products in either Belo Horizonte, Rio de Janeiro, or São Paulo, depending on the current prices. At the time of interviewing about 150 commercial dairy farmers were estimated to be living in the township. The 101 interviews were obtained from the farmers living closest to the township center

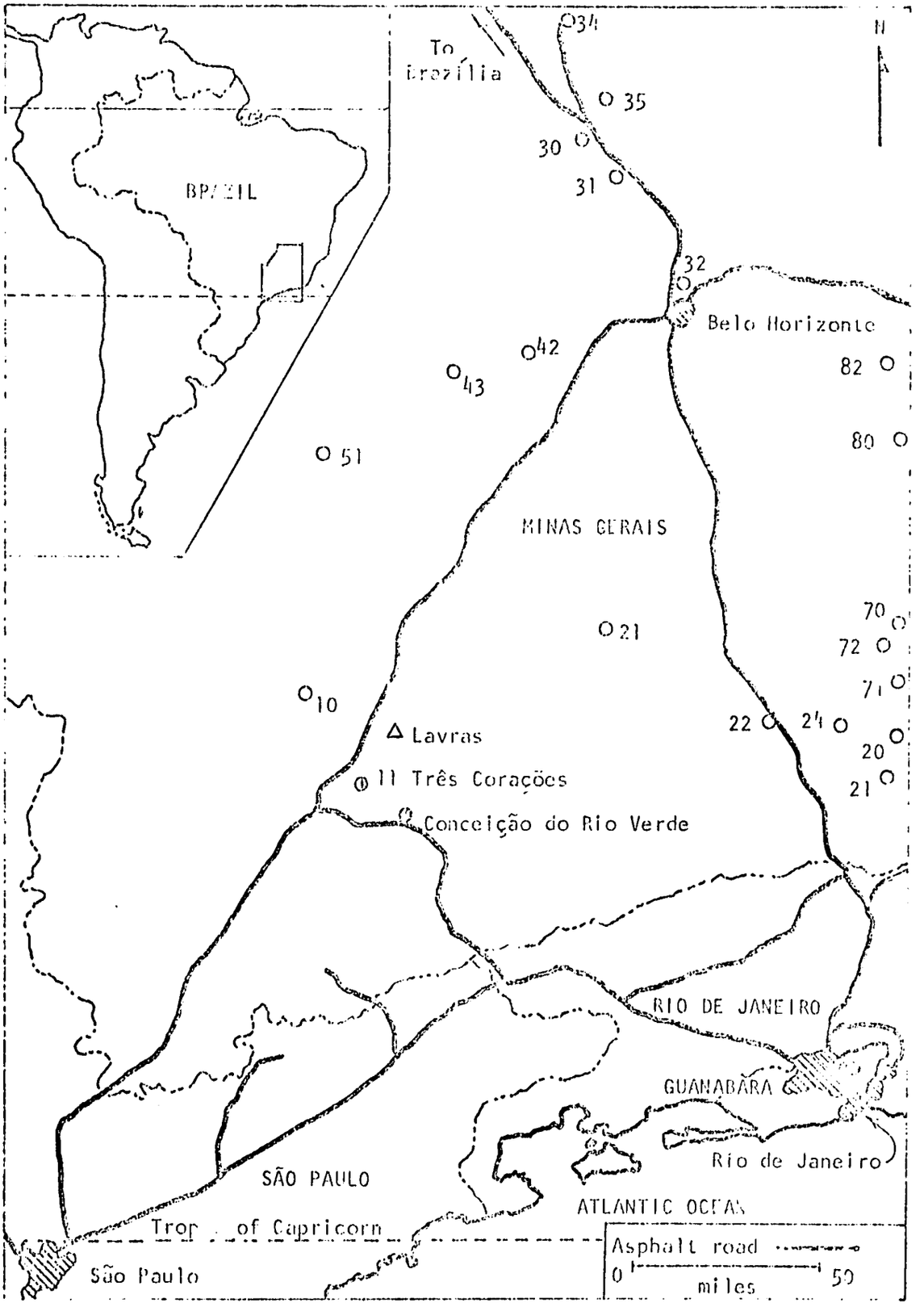

Figure 3.1 Map showing location of Conceição do Rio Verde and twenty Phase II communities including Três Corações (see Table 3.24 for key to community code numbers).

(see Figure 3.2).

In comparison, Três Corações (population approximately 30,000) at the time of the research had several formal organizations which were actively promoting the adoption of improved dairy practices. The Nestle Corporation built one of its milk processing plants in Três Corações in about 1956. In addition to providing a greatly increased demand for milk, the plant has an extension department which has been an active change agent. ACAR, the rural extension agency of Minas Gerais, opened an office in Três Corações in about 1952 and has had an active information program on dairy innovations since the late 1950's. The federal department of agriculture and the state department of agriculture have had agents testing for and vaccinating against common cattle diseases. Early in 1967 the federal department of agriculture opened an office in Três Corações to introduce the practice of artificial insemination.

At the time of the research there were estimated to be about 400 commercial dairy farmers living in the township. The research plan had called for interviews with about 100 dairy farmers living in the communities of Abelhas and Boa Esperanca lying north of the township center. Time permitted only 47 interviews. In the rest of this report we will refer to the farmers as living in the township of Três Corações rather than using the community names.[6]

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[6]The distinction between the Brazilian words *município* and *comunidade* should be clarified. The *município* is the smallest recognized political unit in Brazil. Each *município* has a locally elected *prefeito* or mayor. Thus, the word *município* seems best translated into English as "township." The *comunidade* refers to a smaller geographical locality or neighborhood within the *município*. This report simply translates *comunidade* as community. Other reports of the Brazil

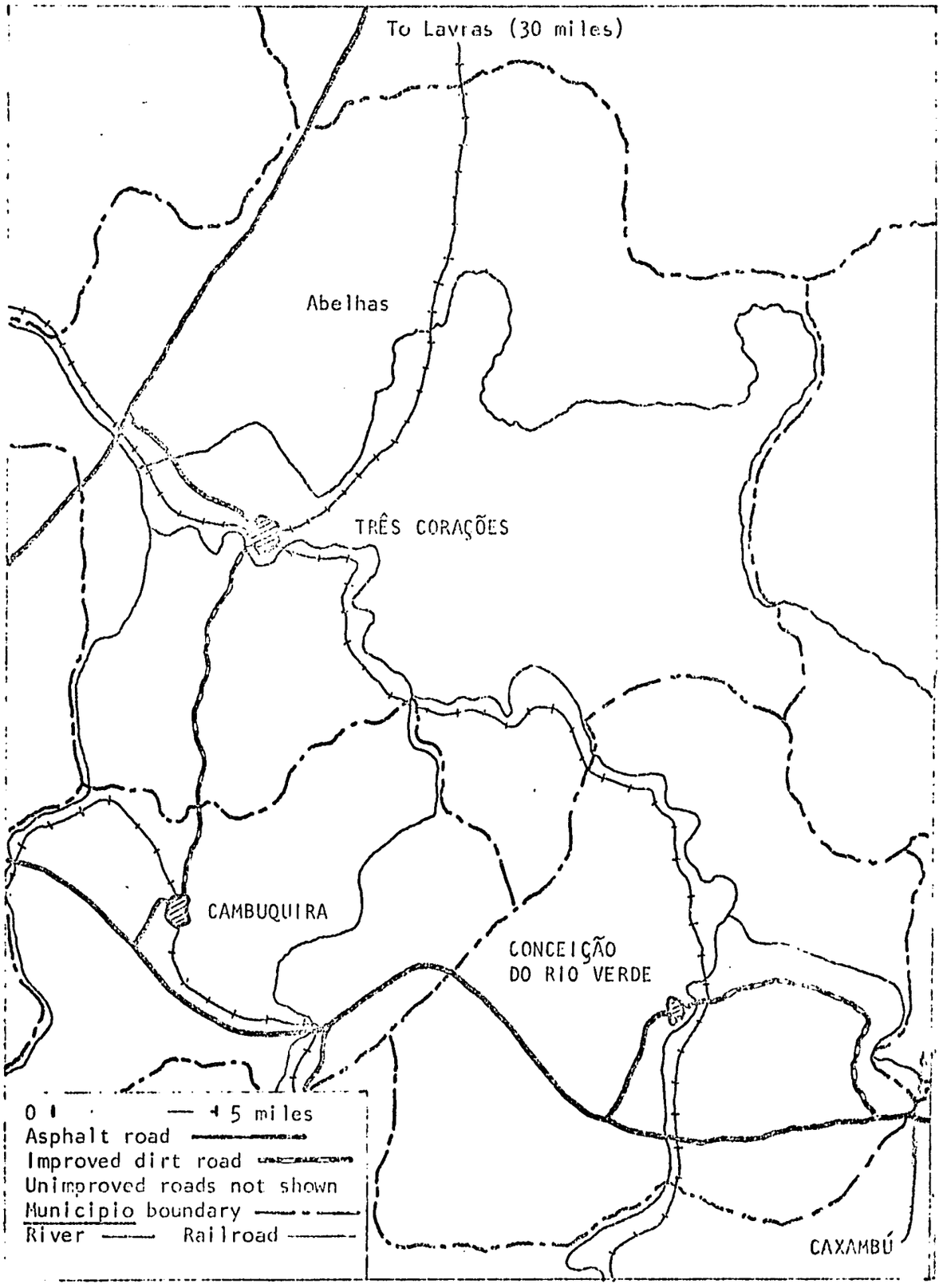

Figure 3.2 Map of Conceição do Rio Verde and Três Corações

As shown in Figure 3.3 both Conceição do Rio Verde and Tres Corações ranked high on an economic development scale constructed by Stanfield (1968) for the Phase II communities. Stanfield constructed his community economic development scale in the following manner. The economic variables for the individual respondents in each community were aggregated to obtain a community score for the economic variables. (The average number of respondents in each community was 65; the range ran from 35 to 82.) These aggregated scores were most usually presented as percent of the respondents with a particular characteristic or as a mean or median value on a particular variable. Examples were percent with motor vehicle, mean income, and median farm size. In a principal-axis factor analysis of the 24 aggregated economic variables all but about three or four loaded heavily on a single factor in the principal axis solution, which accounted for about 50 percent of the variance. Stanfield concluded that the unweighted average of the four variables which loaded most highly on the principal axis could be taken as a fairly good measure of the community's relative economic development. These four variables (with their factor loadings in parentheses) are

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Diffusion Project have used the term "county" as a translation of the word município. However, since counties in the United States are often broken down into the smaller political units of townships, this translation seemed inappropriate. The various regions of the state of Minas Gerais are more closely equivalent to the concept of counties in the United States. For example, both Conceição and Três Corações are located in the region known as Sul de Minas. In this report we shall use the word community in two slightly different ways. One use will refer to the direct translation of the word comunidade from the Portuguese; the other use will refer to a grouping of individuals who live in the same geographical area and interact more frequently with individuals within the community than outside the community. Thus in this sense we shall also refer to the dairy farmers living in the township of Conceicao as a "community." It should be noted that the data collected in Phase II of the Brazil Diffusion Project was based on the Portuguese meaning of the word comunidade.

as follows: percent of farmers with running water in their houses (.934), percent with a bathroom in the house (.940), percent with electricity (.909), and the percent owning a radio (.935).

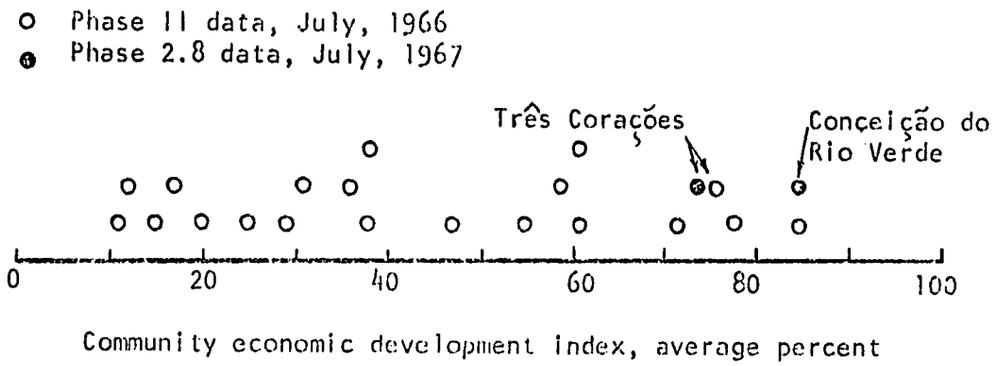
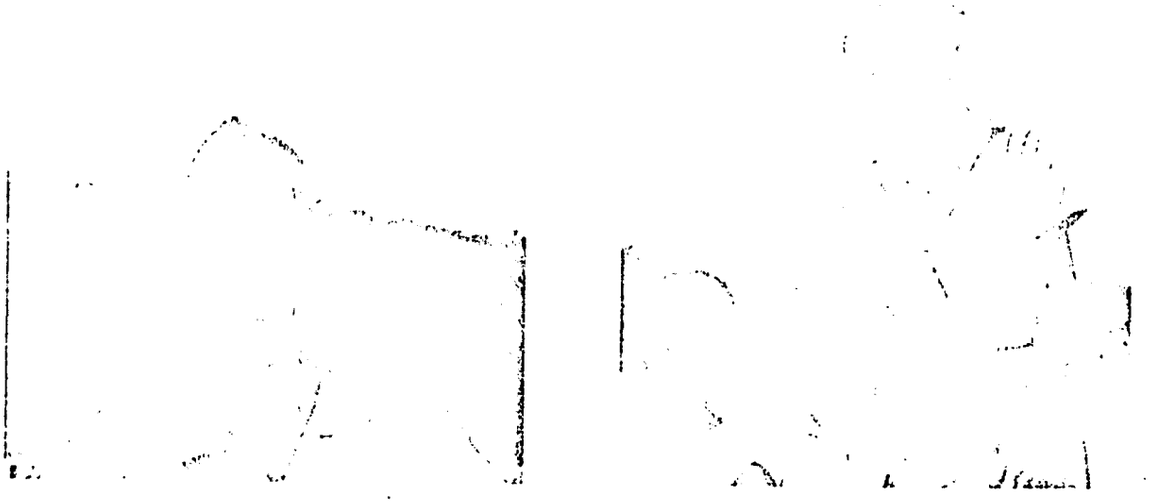
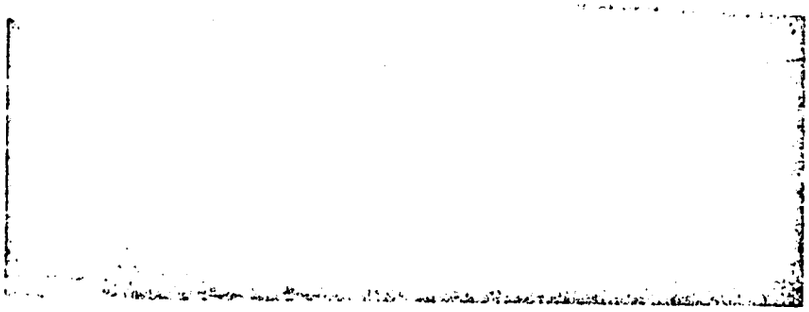


Figure 3.3 Economic development of 21 rural communities in Minas Gerais, Brazil. The community development index is computed as the average of the percentages of farmers possessing piped water, inside toilet, electricity, and radio.

The Farmer and His Dairy Operation

In this section we expand our first impression of Conceição as a farming community by looking more closely at the general characteristics of an average farmer and his dairy farming operation (see, for example, Figure 3.4). Table 3.1 summarizes some of the demographic and general characteristics of the average dairy farmer in Conceição as compared with the dairy farmers in Três Corações and with dairy farmers and nondairy farmers from the Phase II sample. Thus the typical farmer in Conceição is 46 years old, has a family of six besides himself and an average of three children less than fifteen years old. He has had at least some secondary schooling (an average of 6.6 years total of schooling). Probably what is most important for the diffusion of innovations through the community is that about 7 percent of the





Farmstead with forage grass plot (two-thirds cut back) in right foreground and hillside silo in right background

Figure 3.4 Mineiran farmers and farmstead.

TABLE 3.1 Demographic and Economic Characteristics of Farmers in Conceição do Rio Verde, Três Corações and Other Communities in Minas Gerais

The numbers in the table represent percent of respondents except where indicated.

Characteristic	Conceição do Rio Verde N = [illegible]	Três Corações N = 46	Phase II w/ Cows N = 816	Phase II w/o Cows N = 491
Age				
Mean (years)	46	47	45	43
Length of residence in community				
Mean (years)	27	25	(NA)	(NA)
Standard deviation (years)	18	16	(NA)	(NA)
Length of time as a dairy farmer				
Mean (years)	20	18	(NA)	(NA)
Standard deviation (years)	11	14	(NA)	(NA)
Family Size				
Mean (number of members)	6	6	(NA)	(NA)
Education				
Mean (years)	6.6	4.3	1.2	0.9
None	1	4	12[a]	28[a]
Primary (1-3)	1	39	87	71
Primary (4-5)	40	35	1	1
Secondary (6-9) . . .	33	13	*	-
High (10-12)	8	7	-	-
University	7	2	-	-
Percent who attended an agricultural school	5	0	(NA)	(NA)
Literacy (reads 80% of words correctly) . .	39	83	67	44
Trips to cities (one or more trips to Belo Horizonte, Rio de Janeiro or São Paulo .	42	26	61[b]	42[b]

TABLE 3.1--Continued

Characteristics	Conceição do Rio Verde N = 97	Três Corações N = 46	Phase II w/ Cows N = 816	Phase II w/o Cows N = 491
Land owned				
Mean (hectares)	164	190	98	21
Median (hectares) . . .	120	100	48	5
Loans for dairy farming operation (one or more during last five years)				
Any source	34	50	60[c]	25[c]
Bank	25	30	33[d]	18[d]
ACAR	-	15	27[d]	8[d]
Friend	13	9	4[d]	6[d]
Income				
Median (gross in US$) .	¢2200	$1300	$700	$350
Less than US$350 . . .	8	9	17	53
Over US$3500	37	17	7	1
Level of Living				
Wood or tile floors . .	98	96	79	49
Water piped into house	89	78	53	19
Toilet in house	88	59	42	13
Water filter	87	76	74	38
Radio	87	98	78	36
Agricultural machines .	86	78	66	24
Electricity	78	61	41	14
House in town	69	44	27	15
Motorized vehicle . . .	67	33	21	5
Television set	46	20	6	2

NA Not available. * Less than 0.5 percent. - Represents zero.

[a]These distributions for years of education for the Phase II communities seem seem suspiciously low. In Phase 2.5, during which 317 of the Phase II respondents were reinterviewed, 14 percent reported attending school 4 or 5 years, and 3.4 percent reported attending school 6 or more years.

[b]City of over 40,000.

[c]Ever received a loan for farm.

[d]Source to which request for most recent loan was made.

farmers have had some university education and 5 percent have attended an agricultural school. The literacy rate is high--89 percent. The farmers can be considered relatively cosmopolitan in view of the fact that 42 percent had visited São Paulo, Belo Horizonte, or Rio de Janeiro during the previous year. The typical farmer (median) owned 120 hectares of land --one hectare equals 2.47 acres.

Thirty-four percent of the farmers reported taking at least one loan during the previous five years. The median gross income for Conceição dairy farmers came out to be US$2200, a little less than double that for the dairy farmers in Três Corações. Inspection of the level-of-living variables in Conceição indicates a relatively high standard of living. Among other things, 69 percent of the farmers own houses in town--generally regarded as a significant status symbol among the rural farmers in the interior of Brazil, and 26 percent reported owning a television set. The general conclusion after reviewing this table is that the dairy farmers in Conceição are a relatively prosperous group of individuals. Similarly the data in Table 3.2 indicate that the farmers in Conceição have made a somewhat greater shift from animal power to mechanized power for their farm vehicles than have the farmers in Três Corações. The data in Table 3.3 indicate that the farms in Conceição were somewhat more advanced in their adoption of stable improvements than were the farmers in Três Corações. Unfortunately, data on farm vehicle ownership (except for data in Table 3.1) and on stable improvements were not available for the Phase II communities, so no comparisons could be made with respect to these farm characteristics.

TABLE 3.2 Farm Vehicles Owned by Farmers in Conceição do Rio Verde and Três Corações

Percent owning at least one vehicle.

Vehicle	Conceição do Rio Verde N = 97	Três Corações N = 46
Horse cart	22	15
Ox cart	47	61
Pick-up truck	30	11
Truck (full-size)	22	-
Tractor	24	11
Car	33	20

- Represents zero.

TABLE 3.3 Stable Improvements in Conceição do Rio Verde and Três Corações

Percent of dairy farms having improvement.

Stable improvement	Conceição do Rio Verde N = 97	Três Corações N = 46
Calf pen	88	59
Covered corral	87	72
Feed trough in corral	81	91
Divided corral	72	67
Water in corral	61	50
Concentrate trough in stable . .	61	54
Stable floor of rock or cement .	56	39
Bull pen	33	11

Table 3.4 contains important summary data on dairy herd size and milk production on dairy farms in Conceição, Três Corações, and the Phase II communities. The dairy cows in Conceição were about 5 percent more productive in terms of milk produced per year by an average cow than were the cows in Três Corações and approximately 57

percent more productive than were the dairy cows in the Phase II communities. Figure 3.5 is a plot of Lorenz curves which show the degree of concentration of dairy cow ownership in Conceição do Rio Verde and Três Corações. As can be seen from the two curves, ownership of dairy cattle is more evenly distributed in Conceição do Rio Verde than in Três Corações.

Technological Change in Dairy Farming: The Innovations

In addition to the normal problems of dairy farming, dairy farming in the tropical regions has its own special problems (Hodgson and Reed, 1961). A number of factors influence an animal's production of milk, including breed, size, age, gestation, lactation period, dry period, ambient temperature, feed, frequency of milking, method of milking, and general health. In general, the recommended practices for combating the factors which would reduce quantity of milk production fall under three general categories: breeding, feeding, and general care.

Although this is not the place to go into a detailed technical discussion of dairy farming, nevertheless it is useful to review the characteristics of the various practices that are currently diffusing among the dairy farmers in Minas Gerais. The characteristics of an innovation obviously effect the rate of its diffusion through a community (cf. Rogers, 1962, pp. 121-47).

Breeding

Improvement in breeding dairy herds is currently receiving much emphasis from dairy farmers as a way to increase milk production. Many of the cattle in this section of the country are the "common" variety

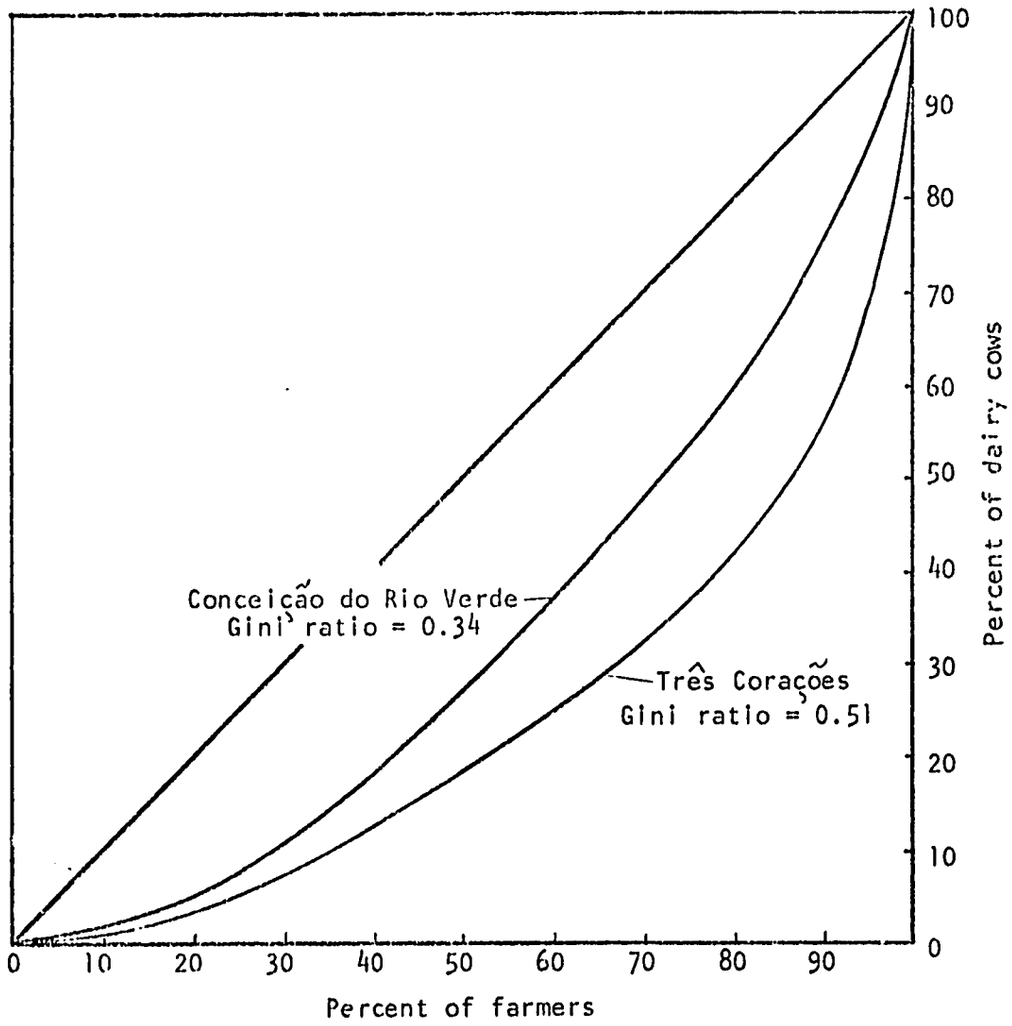


Figure 3.5 Lorenz curves showing concentration of dairy cow ownership in Conceição do Rio Verde and Três Corações.

TABLE 3.4 Dairy Herd Size and Milk Production in Conceição do Rio Verde, Três Corações, and Other Communities in Minas Gerais[a]

Item	Conceição do Rio Verde N = 97	Três Corações N = 46	Phase II communities N = 787[b]
Dairy cows per farm			
Mean	42	35	(NA)
Median	40	20	(NA)
Dairy cows in lactation per farm			
Mean	29	23	11[c]
Median	27	15	9
Percent of year average cow is in lactation[d]	67	63	58
Average liters of milk per cow per year[e]	1240	1180	790[f]
Daily milk production per farm during wet season (liters per farm per day)			
Mean	151	132	51[c]
Median	120	60	30
Daily milk production per farm during dry season (liters per farm per day)			
Mean	134	94	35[c]
Median	100	45	20

NA Not available.

[a]For purposes of comparison the following data are included for the state Michigan. The average dairy herd size is 35 to 40 cows. The average cow is in lactation 83.5 percent of the years (305 days) and produces 4250 liters of milk per year (9600 pounds per year). Conversion factors: 1 liter equals 1.057 liquid quarts and 1 quart equals 2.1 pounds of milk. (Personal communication with Dr. Peter Spike, Department of Dairy, Michigan State University, November, 1968.) The average milk production figures per head for the entire dairy herd in the United States are as follows: 2200 liters (5300 pounds) per cow per year in 1950, and 3000 liters (7000 pounds) per cow per year in 1964. (Calculated from data appearing in U. S. Bureau of the Census, Pocket Data Book, USA 1967, December, 1966, p. 227.)

[b]Other tables in this chapter give an N of 816 for the number of dairy farmers in the Phase II sample. The N of 787 reported in this table

TABLE 3.4--Continued

excludes 29 farmers who gave ambiguous or inconsistent answers to four questions dealing with herd size.

[c]Based on an N of 780 which excludes 7 farmers who owned more than 99 cows but who were coded as owning 99.

[d]Calculated as the average number of dairy cows in lactation per farm divided by the average total number of dairy cows per farm. Since the data on the average number of total cows were not available for the Phase II communities, the figure of 58 percent entered above was calculated using data from Mattoso (1966, p. 4). He reported that cows in lactation comprised 27.1 percent of the total dairy herd (which included bulls, calves, etc.) in the milkshed of Belo Horizonte and that cows not in lactation comprised 19.8 percent of the dairy herd.

[e]Calculated as the average daily milk production per farm (the average of the wet and dry season production figures) divided by the average total number of cows per farm and multiplied by 365 days.

[f]Mattoso (1966, p. 3) reported a figure of 806 liters per cow per year for cows in the milkshed of Belo Horizonte. This is very close to the figure given in the table above. The comparable figures for cows in the milkshed of São Paulo and Rio de Janeiro were reported as 866 liters per cow per year and 1171 liters per cow per year respectively.

which means that they have not been selectively bred. There are two important pure-bred breeds which are beginning to play a major role in Brazilian dairy farming. These are the Zebu, imported from India, and the Dutch, imported from Holland. The Zebu breed, although it produces less milk than the Dutch breed, nevertheless has the advantage of being much more resistant to tropical diseases and parasites. The Dutch breed produces more milk but requires better care than does the Zebu or common breed.

The common way for a farmer to improve his dairy herd is to purchase or borrow a pure-bred bull. Only a very few farmers were using artificial insemination in developing their herds. As has been

mentioned, in 1967 the federal ministry of agriculture opened an artificial insemination center in Três Corações for the purpose of introducing the practice and providing the necessary supplies and technical assistance to the farmers of the region. The author underestimated the importance of better breeding practices and thus neglected to include any questions about them in the Phase 2.8 questionnaire.

General care

Improved practices are being introduced in the area of general animal care, pest control, and inoculation against cattle diseases. The Phase 2.8 questionnaire asked about nine different practices that might be categorized under general care: maintenance of milk production records, two milkings per day, vaccination against hoof and mouth disease, umbilical cord treatment for calves at birth, vaccination against brucellosis, vaccination of calves against "yearling sickness," grub control, a worm control, and use of tick pesticides.

Feeding

Some of the main efforts which are directed at increasing the levels of milk production are being made in the area of improved feeding and nutritional practices. The Phase 2.8 questionnaire asked about four different feeding practices: silos, forage grass plots, mineral salts, and commercially prepared feed concentrates. Mineral salts provide the dairy cows with the necessary nutrients which may be missing from naturally grown feed. Commercially prepared feed concentrates are a relatively expensive way to provide a complete dairy food ration. The remainder of this section will discuss in greater detail the use of silos and forage grass plots. For reasons to be explained later,

SINDI 2 was applied to simulating the diffusion of silos and forage grass plots among the dairy farmers living in Conceição.

Dairy farmers in this region have long been faced with the problem of the dry season. As shown in Figure 3.6, this region has two

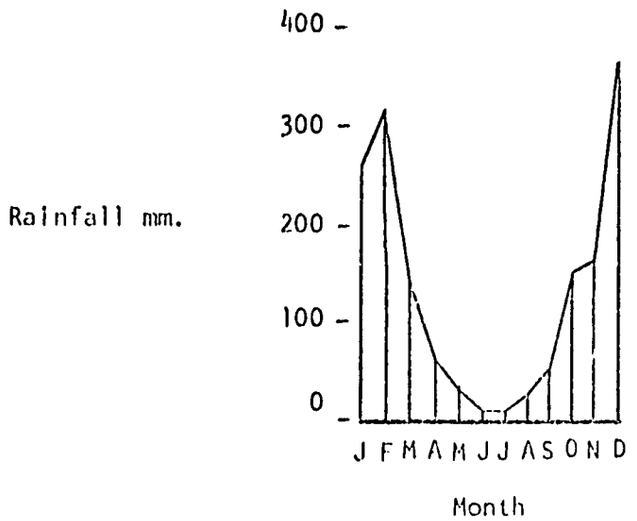
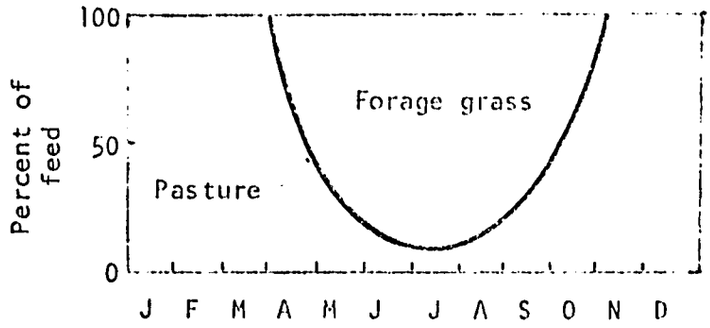


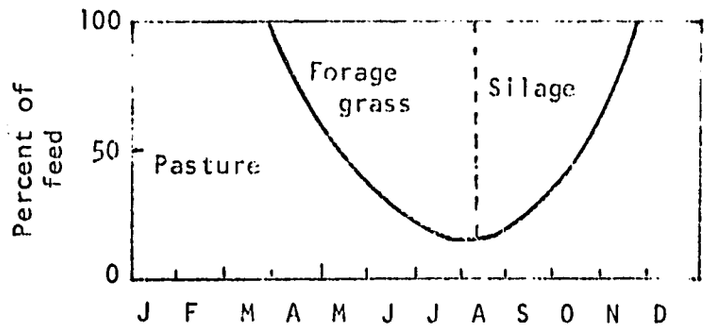
Figure 3.6 Average monthly precipitation. This figure is based on a ten year average for Cambuquira, a township adjacent to both Três Corações and Conceição do Rio Verde. The average annual rainfall totaled to 1625 mm. (Mundim, 1966, p. 2).

distinct seasons, a wet season and a dry season. During the dry season the pastures turn brown and the farmers lose their natural source of feed for their dairy herds. There are three recommended solutions to the problem of providing feed during the dry season (see Figure 3.7): the use of a forage grass plot alone, the use of a forage grass plot in combination with a silo, and the use of a silo alone. The combination of the silo with the forage grass plot is considered by agricultural technicians to be the best solution. One problem with depending only on a forage grass plot is that during July and August there is the danger of

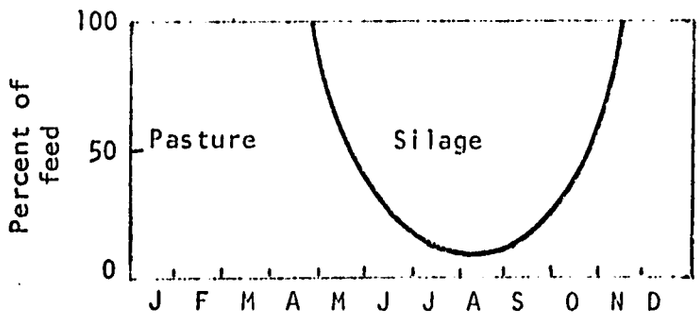
Figure 3.7 Three Approaches to Providing Feed During the Dry Season



Nov: Plant forage grass
Mar - Nov: Cut grass to supplement pasture



Oct - Nov: Plant corn, sorghum, and/or grass
Feb - Mar: Cut two thirds of the grass for silage
Mar - May: Cut back remaining grass to supplement pasture
Jun - Jul: Cut back original two-thirds to supplement pasture
Aug - Nov: Supplement pasture with silage



Oct - Nov: Plant corn, sorghum, and/or grass
Jan - Feb: Prepare silage from grass
Feb - Apr: Prepare silage from corn and sorghum
May - Nov: Supplement pasture with silage

Source: Nunes and Machado (1965, pp. 19-21)

frost which can quickly kill the forage grass and leave the farmer without adequate feed for his herd. To rely solely on silos would require a capital investment great enough for constructing silos of sufficient capacity to provide feed for the entire six-month dry season. In spite of the danger of frost, some farmers prefer relying solely on a forage grass plot because they do not want to make the additional capital investment required to construct a silo.

When a farmer adopts a forage grass plot, he obviously incurs certain capital and labor costs. The labor costs for preparing a one hectare forage grass plot sufficient to support 10 cows during the dry season are summarized in Table 3.5. It can be seen that the labor required depends very much on the degree of mechanization available. The capital costs for constructing a forage grass plot itself are minimal. A farmer can usually obtain free the cuttings which he needs to start his own grass plot. The usual source is a neighbor's plot or a government-sponsored field. After preparing the grass plot most farmers enclose it with a fence in order to keep out stray cattle. This may require a capital outlay for fencing materials.

TABLE 3.5 Labor Requirements to Construct a Forage Grass Plot of One Hectare

In man-hours.

Task	Tractor and plot	Animal and plot	Hoe
Land preparation	6	32	160
Planting with hoe	60	60	60
Total	66	92	240

Source: Adapted from Nunes and Machado (1965, p. 2).

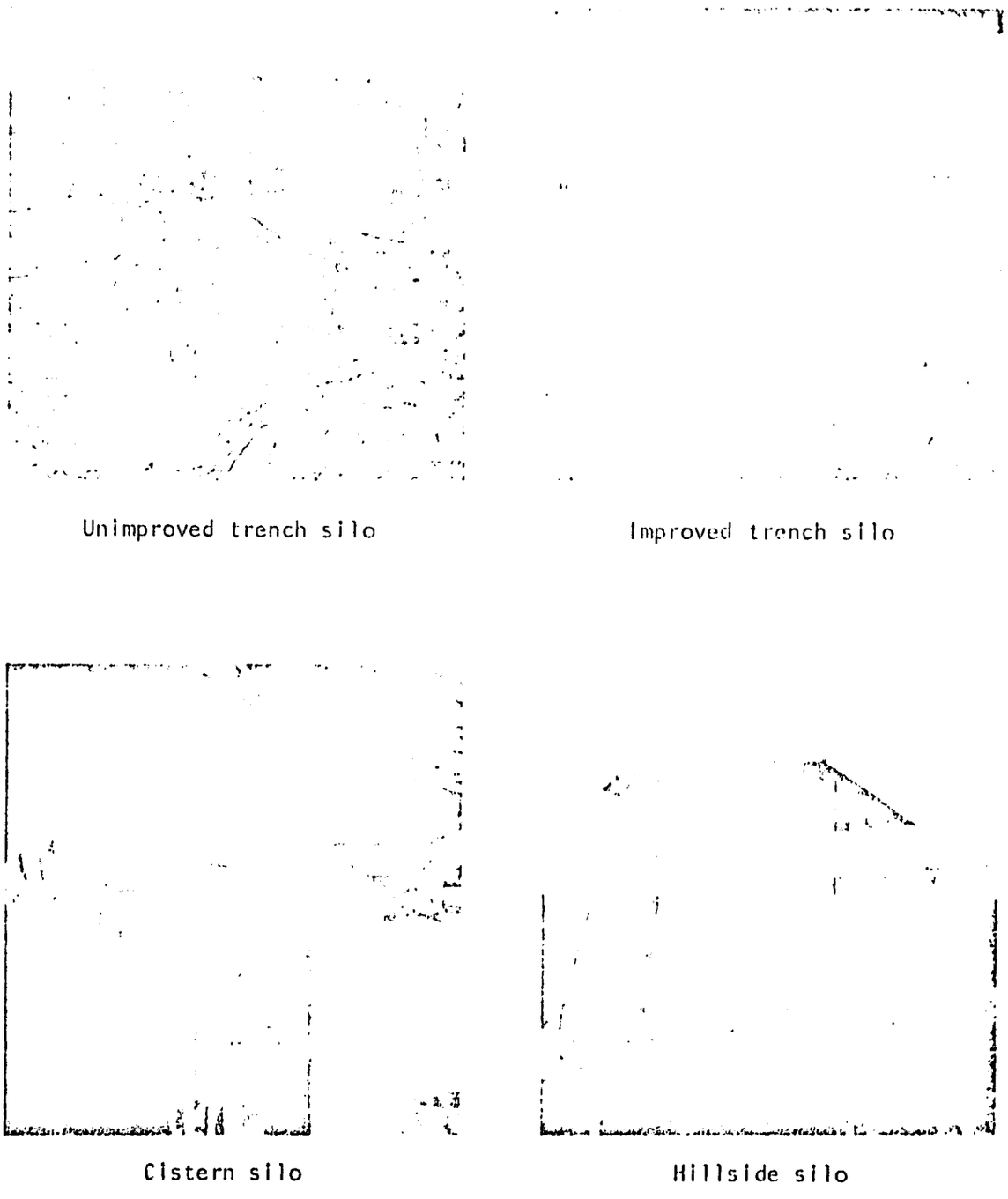


Figure 3.8 Types of silos.

When a farmer adopts a silo, he also incurs capital and labor costs. Four different types of silos requiring varying amounts of capital investment are shown in Figure 3.8: the unimproved trench silo, the improved trench silo (with walls of concrete or stone and a roof), the cistern (or subteranean) silo, and the hillside silo. Most adopters of the silo in Conceição were using the cistern silo although a few farmers with larger herds were using the hillside silo. Most adopters in Três Corações were using the trench silo although many of them had switched to the cistern silo because they found that there were fewer problems of spoilage. In Três Corações there appear to have been two waves in the diffusion of silos. The first wave consisted of the unimproved silo which required a very low capital investment. Most farmers did not consider the unimproved trench silo as a trial before adopting an improved version. Rather, at the time of adoption, they considered that they could be using the unimproved version for the foreseeable future. Then once the farmers had adopted the practice of using silage and noticed that much of the silage was spoiling because of excessive moisture and exposure to air, many began switching to the cistern silo, which was more costly to install but gave better results.[7] The capital investment required to build an improved silo (as shown in Figure 3.8 b-d) is relatively high. An improved trench or cistern

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[7]The trench silo pictured in Figure 3.8 was actually constructed under the supervision of the ACAR Supervisor to be used as a demonstration at the agricultural fair in Três Corações. However, during the two months between the construction of the silo and the opening of the fair, the supervisor had noticed a general disenchantment with the trench silo on the part of many adopters and a shift to the cistern silo. Therefore, he did not make the trench silo an active display at the fair.

silo of 25 metric tons costs about US$600. This capacity will support 10 cows for 2 to 3 months during the last part of the dry season. In addition, it usually is necessary to purchase a motorized chopper which shreds the grass before it is put into the silo. Depending on its size, a motorized chopper can cost the equivalent of an additional several hundred U. S. dollars. Often a smaller farmer will either rent a chopper or cooperate with other farmers to purchase a chopper.

Once the forage grass plot and/or silo have been constructed the farmer must allocate labor to harvest, prepare, and distribute the forage/silage during the dry season. The labor requirements to prepare feed from one hectare forage grass plot are summarized in Table 3.6.

TABLE 3.6 Labor Requirements to Prepare Feed from Forage Grass

These figures are based on average forage grass yields of 40 to 60 metric tons per hectare depending on soil conditions, weather conditions, use of fertilizer. The preparation times to harvest one hectare of corn (25 to 35 metric tons) and one hectare of sorghum (50 to 70 metric tons) would vary proportionately.

Task	Man-hours per hectare
Four harvestings with hoe per year	120
Transporting a distance of 100 meters from field to preparation site	100
Chopping the forage grass with a one horsepower motorized chopper	200
Filling silo (with complete harvest)	60
Distributing forage or silage to feeding trough	50

Source: Adapted from Nunes and Machado (1965, p. 21).

Sources and Channels for Innovation Information

In this discussion no major distinction is made between channels and sources. In one sense sources might be used to refer to personal, face-to-face sources of information about innovations, while channels would refer to the mass media channels of innovation information. Thus, the ACAR agent would be considered a source while a radio program would be considered a channel. But in another sense, the ACAR agent could be considered a channel of information which originates in a research station and is channeled down through the formal organization to the client farmers. In general, we will use the terms "source" and "channel" somewhat interchangeably.

The farmers in Conceição cited a wide variety of different sources and channels carrying information about the various dairy innovations. A summary of the percentages of farmers who obtain information from each of fifteen different channels is found in Table 3.7. For comparison, the percentages of farmers who said during the Phase II interviewing that they usually received agricultural news from various sources are summarized in Table 3.8.

A brief description of each of these channels follows. The channels can be divided into four main groups: mass media, technical experts and commercial agents, miscellaneous institutional sources, and farmer interaction. The channels are discussed in order of their remoteness from the receivers.

Mass media

In Phase 2.8 each farmer was asked about the extent of his exposure to the mass media in general and to specific channels carrying information

TABLE 3.7 General Information Sources Cited by Farmers in Conceição do Rio Verde and Três Corações for Four Dairy Innovations

In percent of farmers citing general source.

General source	Silo		Forage grass plot		Mineral salts		Tick spray	
	CRV	TC	CRV	TC	CRV	TC	CRV	TC
Farmers in same neighborhood	77	74	68	65	71	70	74	72
Farmers in same township . .	79	63	72	54	60	57	75	50
Farmers outside township . .	65	41	62	48	54	35	63	34
Agricultural magazines . .	49	33	57	41	52	33	46	37
Newspapers	46	20	45	22	42	20	32	22
Folders and brochures . .	44	49	52	54	47	48	39	41
Radio programs	31	22	29	26	34	13	24	24
Fairs	30	15	41	20	35	7	28	13
Technical experts[a]	30	28	37	33	27	17	26	20
Store or cooperative . . .	24	17	8	13	48	48	49	37
Commercial agent	11	15	9	9	55	26	34	22
Special meetings	10	20	28	26	10	9	14	17
Agricultural school . . .	10	7	18	13	10	4	9	4
ACAR agent	6	48	6	59	4	44	3	41
Other	4	7	3	4	6	-	5	7

- Represents zero. CRV Conceição do Rio Verde (N = 97).
TC Três Corações (N = 46).

[a]From organizations other than ACAR.

relevant to dairy farming.

Table 3.9 summarizes the number of times the farmer reported reading (or having read to him) metropolitan newspapers during the previous month. Table 3.10 summarizes the extent to which the farmers were exposed to the weekly agricultural page carried in most metropolitan

TABLE 3.8 Usual Sources of News about Agriculture as Cited by Farmers Living in Communities with Extension Agent (Phase II Sample)

In percent of farmers citing source.

Source - Channel	Farmers with cows N = 816	Farmers without cows N = 491
Radio	74	49
Neighbors	63	55
ACAR bulletin	51	25
Agronomist or veterinarian	45	19
Magazines	40	19
Newspapers	37	19
Television	7	3

TABLE 3.9 Newspaper Reading by Farmers in Conceição do Rio Verde and Três Corações

In percent of farmers reading newspaper.

Frequency of newspaper reading	Conceição do Rio Verde N = 97	Três Corações N = 46
None	20	54
1-10 times per month	25	28
11-20 times per month	15	4
21-30 times per month	40	14

newspapers. Table 3.11 indicates the extent to which farmers in Conceição and Três Corações read agricultural magazines in general. Table 3.12 summarizes the extent of exposure to specific agricultural magazines which were carrying information concerning dairy farming. Tables 3.9 to 3.12 indicate that the farmers in Conceição are considerably more exposed to the print media than are the farmers in Três Corações.

As indicated in Table 3.1, approximately 90 percent of the respondents reported owning a radio. Fifty-nine percent of the respondents in

TABLE 3.10 Exposure to the Agricultural Page in Newspapers of Farmers in Conceição do Rio Verde and Três Corações

In percent of farmers.

Newspaper (City)	Frequency of exposure	Conceição do Rio Verde N = 97	Três Corações N = 46
Jornal do Brazil (Rio de Janeiro)	Never	78	94
	Some issues	2	-
	Most issues	20	6
Correio da Manhã (Rio de Janeiro)	Never	80	96
	Some issues	10	4
	Most issues	10	-
Estado de São Paulo (São Paulo)	Never	78	83
	Some issues	13	13
	Most issues	9	4
Estado de Minas (Belo Horizonte)	Never	89	85
	Some issues	9	11
	Most issues	2	4
Other newspapers	Never	96	98
	Some issues	4	2
	Most issues	-	-

- Represents zero.

TABLE 3.11 Agricultural Magazines Read by Farmers in Conceição do Rio Verde and Três Corações

In percent of farmers.

Reading frequency of agricultural magazines	Conceição do Rio Verde N = 97	Três Corações N = 46
Never	27	39
Occasionally	33	41
More or less regularly	40	20

TABLE 3.12 Exposure to Agricultural Magazines of Farmers in Conceição do Rio Verde and Três Corações

In percent of farmers.

Magazine[a]	Frequency of exposure	Conceição do Rio Verde N = 97	Três Corações N = 46
Revista dos Criadores (São Paulo, 1930)	Never	55	61
	Some issues	30	30
	Most issues	15	9
	Subscription . . .	10	7
O Ruralista[b] (Juiz de Fora, M.G., 1963)	Never	62	85
	Some issues	20	9
	Most issues	18	6
	Subscription . . .	13	4
O Dirigente Rural (São Paulo, 1960, incorporating A Fazenda)	Never	67	83
	Some issues	14	10
	Most issues	19	7
	Subscription . . .	16	4
A Realidade Rural (Belo Horizonte, 1956)	Never	78	83
	Some issues	11	13
	Most issues	11	4
	Subscription . . .	7	2
Coopercotia (São Paulo, 1943)	Never	79	87
	Some issues	9	11
	Most issues	12	4
	Subscription . . .	7	7
Sítios e Fazendas (NA)	Never	74	85
	Some issues	23	11
	Most issues	5	4
	Subscription . . .	4	-
Seleções Agricolas (Rio de Janeiro, 1946)	Never	87	85
	Some issues	11	15
	Most issues	2	-
	Subscription . . .	2	-

TABLE 3.12--Continued

In percent of farmers.

Magazine[a]	Frequency of exposure	Conceição do Rio Verde N = 97	Três Corações N = 46
Boletim da ACAR (Belo Horizonte, NA)	Never	88	61
	Some issues	10	26
	Most issues	2	13
	Subscription . . .	3	4
Boletim da Nestlé (São Paulo, 1966)	Never	90	48
	Some issues	8	22
	Most issues	2	30
	Subscription . . .	1	22
Other magazines (Boletim do Campo, Correio Agro, Pecuário da Acugau, Chácaras e Quintais)	Never	98	100
	Some issues	1	-
	Most issues	1	-
	Subscription . . .	2	-

- Represents zero. NA Not available.

[a]Information in parentheses indicates city of publication and date of first issue.

[b]Even though O Ruralista has the format of a newspaper, it is treated as an agricultural magazine because it deals almost exclusively with agricultural matters and is published bimonthly.

Três Corações reported listening at least one hour per day to the radio. More important to the study of innovation diffusion is the frequency with which farmers listen to programs carrying information about new farming practices. Very few radio programs and virtually no television programs carry agricultural information. The one agricultural program most frequently mentioned by the respondents was the Farmer's Hour which at the time of data collection was being broadcast for one half hour during the early evening six days a week. The program was founded

in 1936 and has been produced since that time by the same man, João Anatolio Lima, Agricultural Engineer. The producer estimated that the program on the average receives about 1000 letters a year. A sample script from one of the programs is found in Appendix A. The distribution of frequencies of listening to the Farmer's Hour is found in Table 3.13.

TABLE 3.13 Frequency with which Farmers in Conceição do Rio Verde and Três Corações Listen to the Farmer's Hour[a]

Frequency of listening	Probability of listening to a program	Percent of farmers: Conceição do Rio Verde N = 97	Percent of farmers: Três Corações N = 46
Never	0.00	25	24
Rarely	0.05	25	39
Several times per month	0.10	11	13
One time per week . .	0.20	13	5
Several times per week	0.50	12	13
Most programs	0.80	6	2
Daily	0.95	8	4
Total		100	100

[a]Broadcast by Radio Inconfidência, Belo Horizonte.

The ACAR supervisor in Três Corações reported that he produced a weekly fifteen minute radio program which was broadcast by the local station. However, the Phase 2.8 questionnaire did not specifically ask about this program, and none of the respondents mentioned it when they were asked "Do you listen to some other program about agriculture?"

According to Table 3.7 approximately half of the farmers in both communities reported acquiring information about silo and forage grass plots from folders and brochures put out by various organizations. Field observation indicated that ACAR, the Nestle Corporation, the state

department of agriculture, the federal department of agriculture, and the agricultural colleges in Viçosa and Lavras had distributed most of these folders. Some of the folders were distributed through sub-projects of the Project on Agricultural Commercialization in Minas Gerais which was started in the early 1960's through a joint agreement between the state and federal departments of agriculture, the universities at Belo Horizonte and Viçosa, ACAR and USAID. Some folders were also distributed by the various commercial firms selling products for use by dairy farmers. The ACAR agent in Três Corações indicated that the folders were available at this office and that he would hand them out at special group meetings. Table 3.14 indicates that relatively few farmers had read the ACAR folder "Forage Grass Plot Makes the Difference," which urged farmers to adopt the use of a forage grass plot. However, this was one of several folders which dealt with forage grass plots and silos and had been distributed at various times and places. In general, it was not possible to determine exactly where and when various folders dealing with forage grass plots and silos had been distributed.

TABLE 3.14 Exposure to the Folder "A Forage Grass Plot Makes the Difference" to Farmers in Conceição do Rio Verde and Três Corações

In percent of farmers.

Exposure	Conceição do Rio Verde N = 97	Três Corações N = 46
Never seen	73	57
Has seen	16	15
Has read	11	28

Technical experts and commercial agents

In addition to entering the community via the mass media, information about agricultural innovations enters via technical experts and commercial agents who have contacts with farmers in the community.

Tables 3.15 and 3.16 summarize the degree of contact which farmers reported having with technical agents. Since neither ACAR nor the Nestle Corporation have technical experts working in Conceição, it is not surprising that the farmers there reported little contact with them. The farmers in Conceição reported approximately the same degree of contact with the technical experts of the state department of agriculture as did the farmers in Três Corações but somewhat less contact with veterinarians. There were three veterinarians working

TABLE 3.15 Frequency of Contact with the ACAR Supervisor of Farmers in Conceição do Rio Verde, Três Corações, and Other Communities in Minas Gerais

In percent of farmers in contact with ACAR supervisor.

Number of contacts in past year	Conceição do Rio Verde N = 97	Três Corações N = 46	Phase II w/ cows N = 816	Phase II w/o cows N = 492
0	95	43	28	64
1-5	-	13	35	24
6-10	5	11	12	3
11-20	-	20	12	5
20+	-	13	12	4

- Represents zero.

in the region surrounding Conceição and Três Corações. Two veterinarians connected with the state department of agriculture had offices in Caxambú and Cambuquira but also served Conceição and Três Corações respectively. A veterinarian who represented the federally sponsored

campaign to control hoof and mouth disease, tuberculosis, brucellosis, and rabies maintained an office in Três Corações. Thus the farmers in Três Corações had somewhat greater opportunity to interact with a veterinarian than did the farmers in Conceição.

TABLE 3.16 Frequency of Contact with Other Technical Experts by Farmers in Conceição do Rio Verde and Três Corações

In percent of farmers.

Number of contacts in past year	Veterinarian		State dept. of agriculture		Nestlé Corp.		Other[a]	
	CRV	TC	CRV	TC	CRV	TC	CRV	TC
0	84	67	82	78	97	70	90	91
1-5	6	26	6	13	3	15	8	5
6-10	3	3	4	2	-	7	-	2
11-20	3	2	3	2	-	4	1	2
21+	4	2	5	5	-	4	1	-

- Represents zero. CRV Conceição do Rio Verde (N = 97).
TC Três Corações (N = 46).
[a]Private; Companhia Agrícola Minas Gerais, S.A. (CAMIG); Federal department of agriculture; Bank of Brazil. The percentages for these other sources might have been higher if the sources had been specifically asked about.

The Nestle Corporation opened a milk processing plant in Três Corações in 1956. In 1967 Nestle was buying milk from approximately 2000 producers located in the following townships: Três Corações (350), Lavras (215), Oliveira (280), Machado and Alfenas (230), Bom Sucesso (200), Campo Belo (400), andParaisopolis (180). Extension agents from Nestlé worked in each of these townships. The supervisor of the agents said that each agent tried to visit each producer at least once a year. Through its agents Nestlé made available to its producers technical advice, cuttings for forage grass, vaccine for hoof and mouth disease,

and assistance in silo construction plus limited credit. Of the 46 respondents in Três Corações, 36 respondents (78 percent) reported that they sold their milk to Nestlé. However only 30 percent of the respondents reported any contact with the Nestlé agent during the previous year. The supervisor at Nestlé reported that the agent for Três Corações had not been able to contact all producers because there were so many there.

Farmer contact with traveling sales representatives from the major chemical and pharmaceutical companies is summarized in Table 3.17.

TABLE 3.17 Frequency of Contact with Commercial Agents by Farmers in Conceição do Rio Verde and Três Corações

In percent of farmers.

Number of contacts in past year	Sivan		Pfizer		Squibb		Other[a]	
	CRV	TC	CRV	TC	CRV	TC	CRV	TC
0	67	92	76	85	85	94	70	83
1-5	28	6	22	7	14	4	20	11
6-10	4	-	2	4	-	-	8	4
11-20	1	2	-	2	1	2	2	2
20+	-	-	-	2	-	-	-	-

- Represents zero. CRV Conceição do Rio Verde (N = 97).
TC Três Corações (N = 46).

[a]Bayer, Sambra, Rhodia, Tortuga, Ertap, Lepetit, Couper, Shell, Micalvita, Provine, I.S.A. Most all of these companies including Squibb, Pfizer, and Sivan had regional offices in São Paulo. Many had offices in Belo Horizonte.

These representatives generally were selling mineral salts, grub and tick pesticides, vaccines, and medicines. Thus, in Table 3.7 it is not surprising that commercial agents were cited much more frequently as sources of information for mineral salts and tick spray than for silo and

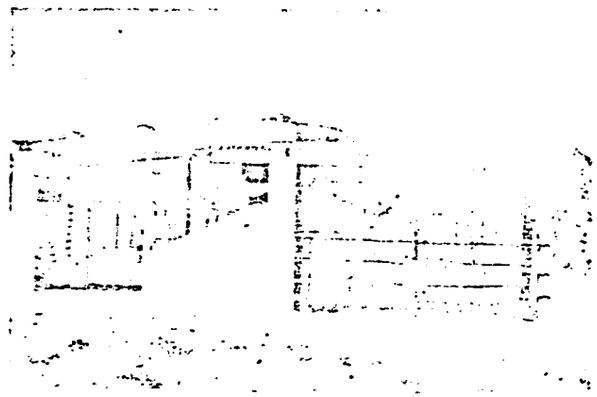
forage grass plot. Approximately 10 percent of the farmers mentioned the commercial agents as information sources for silo and forage grass plot.

Miscellaneous sources

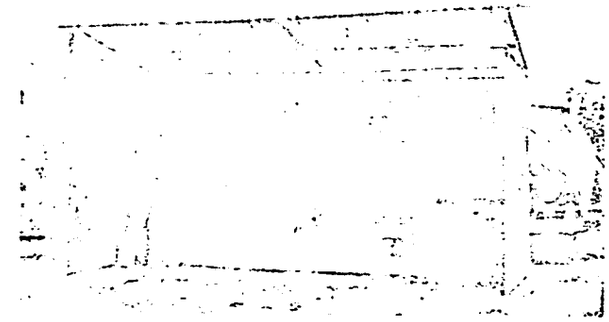
Farmers also reported securing information about dairy innovations from the following sources: agricultural fairs, commercial stores and cooperatives, meetings about the practices, and agricultural schools.

According to Table 3.7 an average of 38 percent of the farmers in Conceição and an average of 18 percent in Três Corações mentioned fairs as information sources for the four innovations. The nearest fair for farmers in Conceição was the Caxambú fair which had been held annually for about 20 years. Três Corações held its first fair in 1966; prior to that, farmers would most frequently attend the fairs in Lavras or Caxambú. Seventy-two percent of the 46 respondents in Três Corações reported attending the Três Corações fair in 1966. Attendance at fairs in Lavras and Caxambú is summarized in Table 3.18. Figure 3.9 indicates various ways in which a fair can influence farmers to adopt improved farming practices.

Commercial stores and cooperatives were the sources for purchasing many of the inputs for dairy farming so it is natural that farmers would also cite these as sources of information. As in the case of commercial agents, the stores and cooperatives were more frequently cited as information sources for products such as mineral salts and tick spray than for practices such as using a silo or using a forage grass plot (see Table 3.7). Respondents reported visiting a store or cooperative an average of 25 times per year.

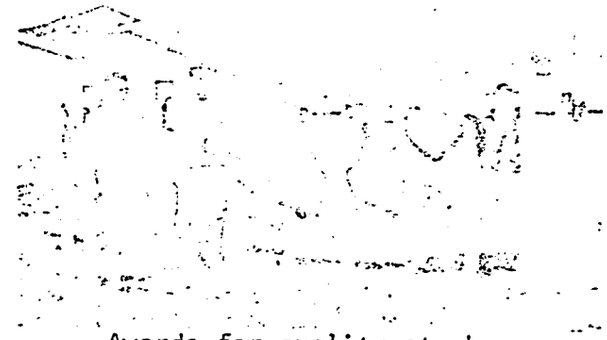


Promotion of stable improvements
by Nestlé Corporation



Chemical products for dairy farming

Promotion of motorized choppers
for feed preparation



Awards for quality stock

Figure 3.9 Agricultural fairs: influence toward innovation adoption.

TABLE 3.18 Attendance at Agricultural Fairs by Farmers in Conceição do Rio Verde and Três Corações

In percent of farmers. Respondents also reported infrequent attendance at fairs in Alfenas, Pouso Alegre, Belo Horizonte, Varginha, Cruzeiro, São Paulo, Uberaba, Sete Lagoas, and Itajubá.

Number of times attended fair in last nine years	Caxambú fair		Lavras fair	
	CRV	TC	CRV	TC
0	15	72	89	72
1-3	31	15	11	24
4-6	9	4	-	2
7-9	43	9	-	2

- Represents zero. CRV Conceição do Rio Verde (N = 97).
TC Três Corações (N = 46).

An average of 15 percent of the respondents in Conceição and 18 percent of the respondents in Três Corações reported obtaining information at special meetings concerning the four different practices. It was not possible to obtain specific information on the nature of these meetings. Sometimes the extension agent would hold small group meetings at which he would demonstrate either how to use a practice or the results of a practice. One farmer in Conceição recalled a meeting held in 1959 in Caxambú during which a high official in the state department of agriculture discussed new dairy farming practices.

Approximately 12 percent of the farmers in Conceição and 7 percent of the respondents in Três Corações mentioned agricultural schools as sources of information about dairy farming practices. Seven percent of the respondents in Conceição reported attending an agricultural school as students while none so reported in Três Corações. Thus some respondents may have obtained innovation information while they were students; others must have obtained information through visits to

agricultural schools. The nearest agricultural college was located at Lavras, about 45 miles from Três Corações.

Farmer interaction

The most frequently cited sources of information about new practices were other farmers, as indicated in Table 3.7. In this table sources were divided into three categories according to whether they lived in the same neighborhood as the respondent, in the same township, or outside the township. In Conceição an average of 73 percent of the farmers cited other farmers in the same neighborhood as general sources of information about the four innovations included in Table 3.7; an average of 71 percent of the farmers cited other farmers in the same township; and an average of 61 percentcited farmers outside the township. The fact that there was a relatively high percentage of farmers who cited farmers outside the community suggests that Conceição did not meet the desideratum that the community have well-defined social boundaries with minimal social communication across the boundaries. This situation may have created problems for the simulation since SINDI 2 was not designed to handle interpersonal communication of innovation information across the boundaries of the simulated population. However, as will be seen in Table 3.22 (see page106) a much smaller proportion of adopters, an average of 11 percent, cited farmers outside the township as the most influential source.

Two types of sociometric relationships were deemed to be important for the communication of innovation information from adopters to nonadopters: a respondent's interaction, even though infrequent, with community "opinion leaders," and a respondent's interaction with his

circle of "discussion partners." An "opinion leader" is a member of a community who is frequently named by other members of the community as a credible source for advice and information about certain matters. Opinion leaders are likely to play an important role in the diffusion process because they are usually among the early adopters in the community, and, by definition, they are above average in the magnitude and domain of their influence. "Discussion partners" are those individuals with whom an individual most frequently discusses matters related to a particular enterprise (e.g. dairy farming). Discussion partners play an important role in an individual's decision-making process simply because he interacts frequently with them and they are likely to be an important reference group to him.

The Phase 2.8 questionnaire contained two questions designed to obtain data on these two types of sociometric relationships:

> 1. Who is this region is most listened to or imitated when it comes to matters related to dairy cattle? Who else is listened to or imitated?
>
> 2. Can you give me the names of those persons with whom you usually discuss matters related to dairy cattle, such as problems of work in general, new methods for raising dairy cattle, and so forth? Are there other persons with whom you converse about these matters less frequently?[8]

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[8] Field experience with these two sociometric questions suggests that they should have been asked in reverse order. When the questions were asked in the order given above, the respondents quickly listed several names, in answer to the first question about opinion leaders. When the second question was asked, in many cases either the respondent was reluctant to answer as if he were thinking, "How many more names do I have to give?" or the respondent repeated the names he had given to the first question. Although these answers may have accurately reflected the situation, the author feels that in future questionnaires he would first ask for a list of the respondent's discussion partners and then ask him to "nominate" opinion leaders.

After the complete list of names was given, the interviewer asked the following questions about each name:

(a) What relation is he to you?
(b) Where does he work?
(c) What is his occupation?
(d) How many times do you see him?
(e) How many times do you discuss matters related to dairy cattle?
(f) Ladder scale of credibility: At the top of the ladder is a man in all of whose opinions you have confidence, that is to say, if he gives you ten pieces of advice about dairy cattle you would follow all. At the bottom of the ladder is a man in whose (meddlesome) suggestions you have no confidence, that is to say, if he gives you ten pieces of advice about dairy cattle, you would follow none. On rung five is a man whose advice about dairy cattle you would follow more or less half of the time. Now, please locate on the different rungs of the ladder the names which you cited above.

The two primary questions led to three types of sociometric choices: individuals named solely as opinion leaders; individuals named as both opinion leaders and discussion partners; and individuals named solely as discussion partners.

The 97 respondents in Conceição made 472 sociometric choices or an average of 4.9 choices per respondent. These choices include 189 opinion leaders (40 percent), 143 opinion-leader/discussion-partners (30 percent), and 140 discussion partners (30 percent). Thirty-nine percent of the choices resided in the same neighborhood as the respondents, 50 percent in the same township (but outside the neighborhood), and 11 percent in another township. Table 3.19 shows that, as would be expected, respondents talked more frequently with the discussion partners they named than with opinion leaders. Table 3.20 indicates that the individuals named as both opinion leaders and discussion partners tended to be given the highest credibility rating.

The 46 respondents in Três Corações made 212 sociometric choices or an average of 4.6 choices per respondent. These choices included

TABLE 3.19 Median Test for Frequency of Discussion with Sociometric Choice Types in Conceição do Rio Verde

In percent of citations.

Frequency of discussion with sociometric choice type	Sociometric choice type (Citations by 97 farmers)		
	Opinion leaders N = 189	Opinion-leader/ discussion-partners N = 143	Discussion partners N = 140
More than 2-3 times per month. . .	14	46	65
2-3 times per month or less . . .	86	54	35
Total.	100	100	100

$x^2 = 93.7$; $p < 0.001$.

TABLE 3.20 Median Test for Credibility Ratings of Sociometric Choice Types in Conceição do Rio Verde

In percent of citations.

Credibility rating on a ladder scale ranging from 0 to 10	Sociometric choice type (Citations by 97 farmers)		
	Opinion leaders N = 189	Opinion-leader/ discussion-partners N = 143	Discussion partners N = 140
Higher than 9 (i.e. 10) . . .	35	49	29
9 or less	65	51	71
Total	100	100	100

$x^2 = 13.1$; $p < 0.001$

70 opinion leaders (33 percent), 79 opinion-leaders discussion-partners (37 percent), and 63 discussion partners (30 percent). Seventy-five percent of the choices resided in the same neighborhood community as the

respondents, 19 percent in the same township, and 6 percent in another township. The findings on frequency of discussion and credibility as a function of sociometric types for Três Corações are similar to those for Conceição as reported in Tables 3.19 and 3.20.

Innovation Decision-making

Rural sociologists have divided the innovation decision-making process into five stages: awareness, interest, evaluation, trial, and adoption.[9] Mason (1964) has criticized this conceptualization as being too rigid. In his research he found cases in which there was no trial stage, cases in which the process of evaluation began at first awareness, and cases in which information seeking (part of the interest stage) also occurred throughout the decision-making process -- even after a decision had been made. Rogers and Shoemaker (in press) have suggested a set of four overlapping "functions" or subprocesses. This latter conceptualization is linked more closely to current theories in social psychology. The four functions are:

> Knowledge: the individual becomes aware of the innovation but is not yet motivated to consciously seek additional information.
>
> Persuasion: the individual purposively seeks information about the innovation and begins to develop a favorable or unfavorable opinion toward the new idea.
>
> Decision: the individual chooses among alternative actions -- the simplest choice being adoption or rejection.
>
> Confirmation: the individual seeks to reduce post-decision "dissonance" by seeking more information to support his decision and/or by "proselytizing" others to adopt the innovation.[10]

The Phase 2.8 questionnaire included several questions designed to

---

[9] For a full discussion see Rogers (1962, pp. 81-86).

[10] For a fuller discussion of dissonance reducing behaviors see Festinger (1957).

obtain data on the communication channels from which respondents received information during the decision-making about the four practices. Table 3.21 summarizes the percentages of farmers citing different sources

TABLE 3.21 First Source of Information for Four Dairy Innovations as Cited by Farmers in Conceição do Rio Verde and Três Corações

In percent of farmers citing first source.

General source	Silo		Forage grass plot		Mineral salt		Tick spray	
	CRV	TC	CRV	TC	CRV	TC	CRV	TC
Farmers in same neighborhood	29	36	15	30	12	29	35	39
Farmers in same township . .	29	9	18	7	9	9	22	9
Farmers outside township . .	20	9	30	7	5	4	11	9
Magazine article or ad. . .	1	-	2	2	1	2	1	-
Newspaper article or ad. . .	1	-	2	-	1	-	-	-
Folders and brochures . . .	2	7	2	5	2	4	-	-
Radio programs	-	-	2	-	2	-	1	-
Fairs	-	-	2	-	1	-	-	-
Technical experts[a]	3	11	3	28	4	2	-	2
Store or cooperative	-	-	-	-	4	11	4	9
Commercial agent	-	-	-	-	35	13	1	2
Special meetings	1	4	3	2	-	-	-	-
Agricultural school	7	-	8	-	2	-	2	-
ACAR agent	-	18	-	15	-	13	-	9
Father's farm	1	2	2	2	8	2	10	2
Other	2	2	3	-	2	-	1	2
Doesn't know	4	2	8	2	12	11	12	15

- Represents zero. CRV Conceição do Rio Verde (N = 97).
TC Três Corações (N = 46).

[a]From organizations other than ACAR.

TABLE 3.22 Most Influential Source for Four Dairy Innovations as Cited by Farmers in Conceição do Rio Verde and Três Corações

In percent of farmers citing most influential source except for first row of figures.

Most influential source	Silo		Forage grass plot		Mineral salt		Tick spray	
	CRV	TC	CRV	TC	CRV	TC	CRV	TC
Total number of adopters[a]	62	28	67	36	78	33	74	31
Farmers in same neighborhood	44	43	28	42	18	21	39	42
Farmers in same township . .	28	11	26	11	15	12	24	10
Farmers outside township . .	8	3	22	3	3	-	11	6
Magazine article or ad. . .	6	-	4	-	5	3	1	-
Newspaper article or ad. . .	-	-	1	-	-	-	1	-
Folders and brochures . . .	-	6	-	-	1	6	-	3
Radio programs	-	-	1	-	-	-	-	-
Fairs	3	-	-	-	1	-	1	-
Technical experts[b]	3	15	3	22	8	3	-	3
Store or cooperative	-	-	-	-	4	6	3	10
Commercial agent	-	-	-	-	33	21	3	-
Special meetings	2	-	3	-	-	-	-	-
Agricultural school	6	-	6	-	3	-	3	-
ACAR agent	-	18	1	19	-	21	-	22
Father's farm	-	3	3	3	8	6	11	3
Other	1	-	1	-	1	-	3	-

- Represents zero. CRV Conceição do Rio Verde (N = 97).
TC Três Corações (N = 46).

[a]Number of adopters able to specify most influential source. Includes in some cases farmers who plan to adopt in the near future.

[b]From organizations other than ACAR.

as their first source of information about the four different practices.

Other sources of information utilized during the knowledge and persuasion

processes have already been summarized in Table 3.7. Table 3.22 shows the percentage of adopters who named each source as being the most influential source during the persuasion and decision processes for the four practices.

Some points can be made about the data in Tables 3.7, 3.21 and 3.22. Extension agents were important sources of information and influence in the community in which they worked, in this case Três Corações. Farmers themselves, while important sources in both communities, played a more important role in Conceição because of the absence of formal extension agents.

In addition to being asked about general sources of information, the respondents were asked to name specific sources of information (e.g. the name of another farmer, a particular magazine or newspaper, a particular extension agent, or a particular agricultural fair.) The specific first sources were compared with the specific most influential sources. In 42 percent of the 401 citations of the most influential source, which were tabulated in Table 3.22, the specific first source was the same as the specific most influential source.

The data which has been presented above on the various sources of information and influence does not reveal very much about the process of innovation decision-making. During the field observation an attempt was made to obtain "decision-protocols" by tape recording loosely structured interviews. The results were not totally successful because there was not enough time to perfect the technique. Nevertheless the few "decision-protocols" which were obtained did reveal some factors which the farmers felt were important in their decisions to adopt certain of the practices but which did not come out in the formal

questionnaires. However, in most cases the factors which caused delay from first knowledge to final adoption were not made explicit. More experimentation with techniques for obtaining decision protocols is needed. An abridged decision protocol for a typical dairy farmer in Conceição is found in Appendix B.

Diffusion System Output: Innovation Adoption and Changes in Productivity

In this chapter we have discussed the characteristics and structure of Conceição do Rio Verde as a diffusion system. Conceição has also been compared with Três Corações, a diffusion system in which formal extension agents played important roles in the diffusion process. In the following two sections we shall consider the output of the diffusion system viewed as a communication system and the output of the diffusion system viewed as an economic system.

Communication system output: innovation adoption

The output of a diffusion system viewed as a communication system can be measured in terms of the adoption levels reached in the system for the various innovations. The adoption levels reached in Conceição and Três Corações for 13 dairy practices are given in Table 3.23. Table 3.24 contains data on the diffusion of practices among dairy farmers in the Phase II communities. Comparison of the adoption levels for innovations common to both Tables 3.23 and 3.24 indicates that Conceição had achieved higher adoption levels for various dairy innovations than had the average Phase II community.

The adoption levels found in Três Corações for the 59 farmers

TABLE 3.23 Dairy Innovation Adoption in Conceição do Rio Verde and Três Corações

The figures represent percent of farmers who were regularly using the dairy practice in 1967, except as indicated.

Dairy innovation	Conceição do Rio Verde N = 97	Três Corações N = 46
Grub control	100	91
Vaccination against "yearling disease"	95	100
Tick spray	81	71
(Aware)	(96)	(93)
(Discontinued)	(2)	(-)
Feed rations	76	72
Vaccination against hoof and mouth disease	74	76
Forage grass plot	74	81
(Aware)	(94)	(98)
(Discontinued)	(1)	(2)
Mineral salts	72	65
(Aware)	(95)	(96)
(Discontinued)	(14)	(9)
Silo	65	50
(Aware)	(99)	(98)
(Discontinued)	(-)	(2)
Umbilical cord treatment at birth .	59	48
Two milkings per day	57	30
Worm control	54	57
Vaccination against brucellosis . .	25	30
Records of milk production	12	11

- Represents zero.

interviewed in 1966 during Phase II may also be compared with the adoption levels found for the 46 farmers interviewed in Phase 2.8 in 1967. Thirty-one of the 46 farmers interviewed in Phase 2.8 had been interviewed in Phase II. The adoption levels found in the Phase 2.8 data are

TABLE 3.24 Diffusion of Dairy Farming Practices in 20 Communities in Minas Gerais (Phase II Data)

Item	Code[a]	Três Pontas (Porteira de Taboas) 10	Três Corações (Abelhas) 11	São João Nepomuceno (Rochedo de Minas) 20	São João del Rei (Arcângelo) 21	Santos Dumont (São João da Serra) 22	Bicas (Gameleira) 23	Rio Novo (Goiana) 24	Paraopbe (Picada) 30	Sete Lagoas (Fortuna de Minas) 31	Pedro Leopoldo (Matos) 32	Corinto (Curralinho de Dentro) 34	Cordisburgo (Periquito) 35	Itaúna (Pedra) 42	Divinópolis (Quilombo) 43	Formiga (Albertos) 51	Ubá. (Córrego Alegre) 70	Cataguases (Itamarati) 71	Tocantins (Córrego do Meio) 72	Ponte Nova 80	Alvinópolis 82
Farmers interviewed		31	59	55	61	38	52	56	48	35	18	35	48	36	40	23	27	44	36	23	51
Average herd size. . .		21	14	13	13	11	16	12	13	13	10	7	11	6	8	3	5	7	5	16	11
DAIRY INNOVATIONS		Percent of dairy farmers using innovation in July, 1966																			
Forage grass plot. . .		68	59	76		87	37	25	63	54	33	57	58	41	58	13	11	16	31	52	47
Mineral salts		48	46	56	26	58	67		50	69	89	26	40	33	68	26	26	41	53	65	78
Vaccination[b]		74	59	53	3	82	42	66			11	46	35	42	68	9	15	27	59	13	55
Silo		10	48	2			87	2		14	44		8	3	5	4					
Worm medicine		65		29	18		29	70	15	57	67			22	35	17	7	18			33
Purebred bull			70	38	56			20	69	46	67	40	15	6	10			14	39		
Umbilical cord treat.		39	31	55	25					60					48	26	15		19		
Grub/tick control . .			12	84			2		29	60	-	66	21	28		9	22				-
Forage chopper w/motor		48						23				14			35						24

- Represents zero. A blank space indicates that the innovation was not included in the survey for that particular community. [a]See Figure 3.1 for location of townships in Minas Gerais. [b]Against hoof and mouth disease.

consistently higher -- in fact much higher than would have been expected from just a one year time lapse. Although part of the difference may be attributed to the different samples, the differences raise questions about the reliability of the adoption data. The problem of data reliability will be discussed later.

A table of adoption levels represents a snapshot of the state of a diffusion system at one point in time. However, the diffusion researcher may be more interested in the path by which the system arrived at that state than in a point-in-time adoption level. A cumulative adoption curve shows the cumulative spread of an innovation through a social system over time and also serves to indicate the rate of diffusion. These curves are usually based on the respondent's recall of when he adopted the various innovations. This recall data may be subject to considerable error. Drawing a best-fit curve through the data points plotted as cumulative adoption levels helps to smooth out some of the inaccuracies introduced by using recall data.

Figure 3.10 is a plot of the cumulative adoption curves for tick spray, mineral salts, and forage grass plots in Conceição do Rio Verde. This figure also plots, as a function of time, the cumulative percent of farmers operating dairy farms. It can be seen that approximately 65 percent of the 97 farmers interviewed in 1967 owned dairy cows in 1952. The remaining 35 percent became dairy farmers after 1952. The curve of the cumulative number of new dairy farmers owning dairy cattle can effect the interpretation of the cumulative adoption. If it is assumed that the 63 farmers (65 percent of 97) who were dairy farmers in 1952 and were interviewed in 1967

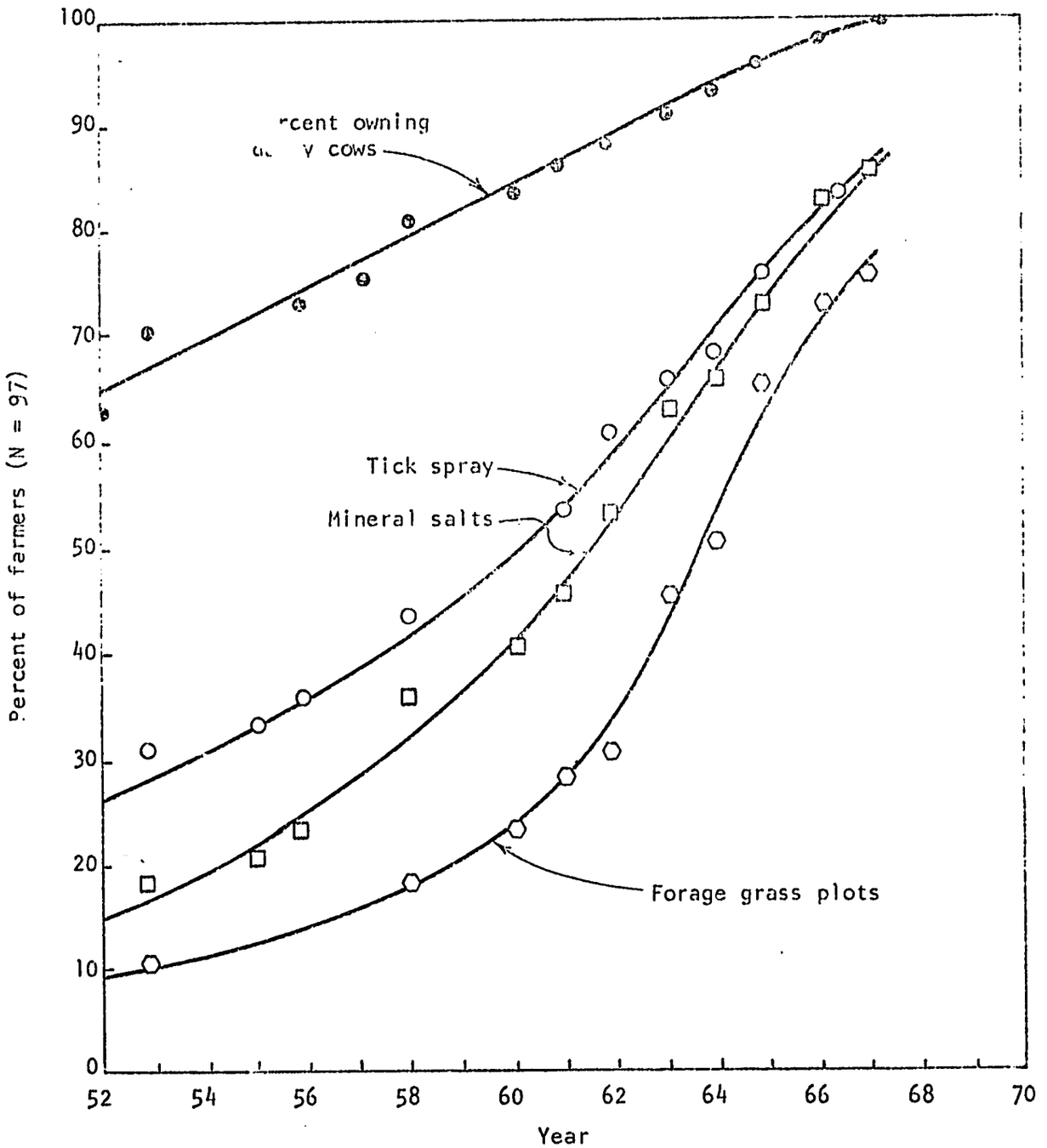

Figure 3.10 Diffusion of three dairy innovations in Conceição do Rio Verde: tick spray, mineral salts, and forage grass plots.

were a representative sample of the dairy farmers in the social system in 1952 (probably not a very good assumption), then the cumulative curve for tick spray, as an example, suggests that 40 percent (25 percent divided by 65 percent) of the dairy farmers in the community in 1952 were using tick spray, not 25 percent as a glance at the curve would imply.

Figure 3.11 illustrates two ways to plot the cumulative spread of an innovation. One curve represents the cumulative number of decision-makers who have adopted the innovation. The other curve represents the cumulative amount of production facilities to which the innovation has been applied. In the case of silo diffusion, this curve represents the cumulative numbers of cows which receive feed from silos during the dry season. Usually, the cumulative curve for production facilities rises faster than the cumulative curve for decision-makers who have adopted the innovation. This deviation occurs for two reasons. First, in any community the production facilities are likely to be unequally distributed among the members of the community. This phenomenon is best illustrated in the form of the Lorenz curves as shown in Figure 3.5. Second, diffusion research has shown that the decision-makers for larger, wealthier production units are likely to adopt innovations earlier than decision-makers for smaller, less wealthy production units. The greater the extent of these two phenomena, the greater the maximum deviation between the two types of cumulative distribution curves. The data on the diffusion of silos in Figure 3.11 show that at the time of data collection in 1967, 65 percent of the farmers had adopted the silo.

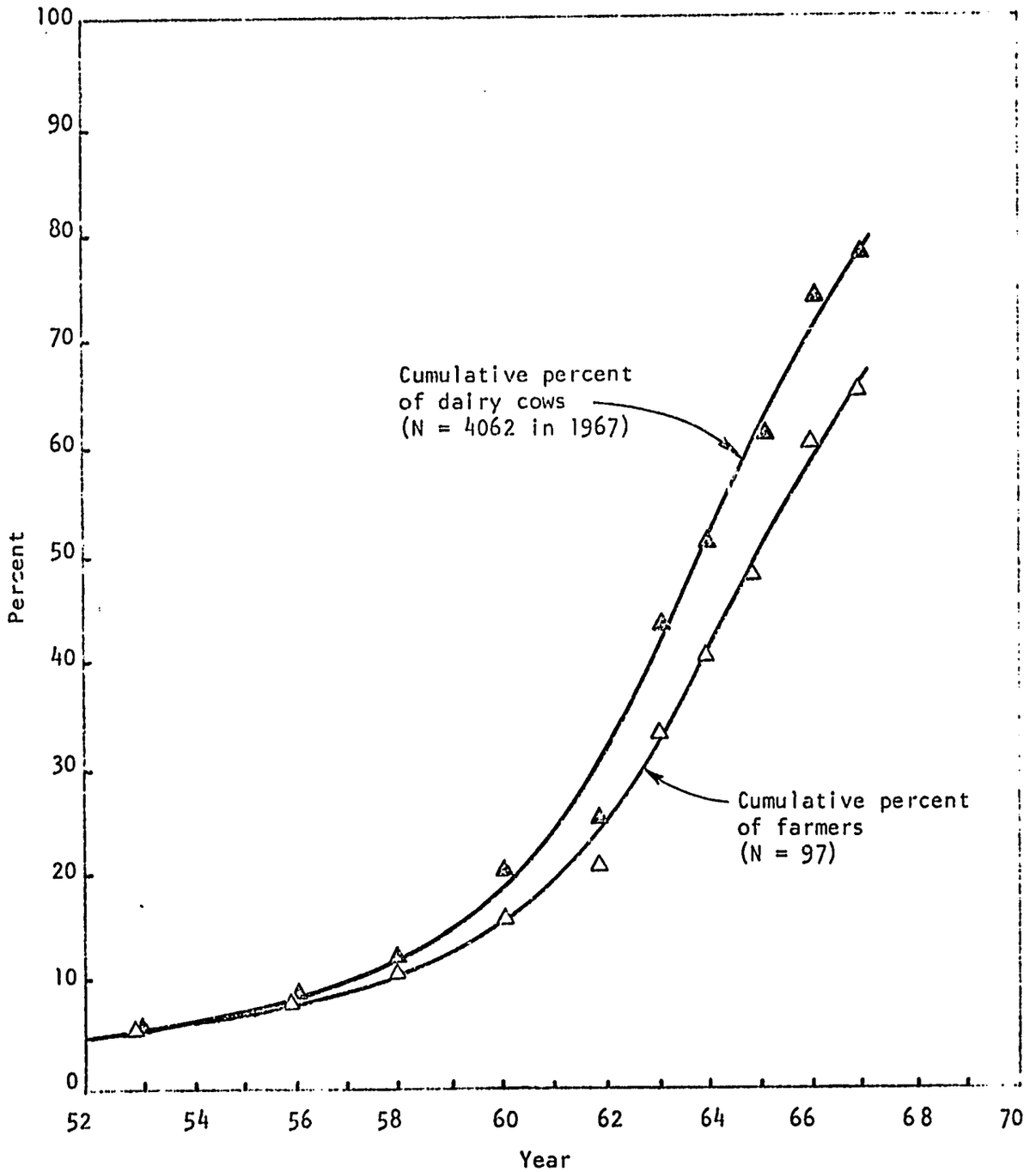

Figure 3.11 Silo diffusion in Conceição do Rio Verde: cumulative percent of farmers using silos and cumulative percent of dairy cows being fed from silos.

These farmers owned 78 percent of the dairy cows in Conceição. It is interesting to note that at least for silo diffusion in Conceição, the largest dairy farmers were not among the very earliest adopters. This fact can be noted in the two cumulative diffusion curves which show very little divergence at the beginning. It appears that the earliest adopters were farmers who owned dairy herds of average size.

The sociologist is usually more interested in the curve which shows the cumulative percent of decision-makers who adopt an innovation. He is interested in the basic process of diffusion among people which results both from their exposure to messages carried by the mass media and interpersonal communication channels as well as from individual decision-making processes. The cumulative adoption curve best summarizes the progress of this overall diffusion process. The economist, on the other hand, is usually more interested in the cumulative curve which shows the percent of production facilities which have been converted to a more modern technology. It is this curve which directly measures the increase in productive capacity of an economic system.

Economic system output:
changes in productivity

The output of a diffusion system viewed as an economic system can be measured in terms of the changes in productivity that occur as improved practices become more widely diffused. Although data on changes in productivity over time are not directly relevant to simulating the diffusion process as such, the data would be of interest if a simulation model of this type were to be incorporated into a larger econometric model.

Monthly data on raw milk purchased by one of the larger milk processing plants in Conceição were obtained for the period from January, 1958, to August, 1967. The data which were normalized to liters per farm per month are graphed in Figure 3.12. It appears that there has been little change in the cycle of peaks and depressions in milk production which occur over this ten year period as a result of the cycle of wet and dry seasons. The average production per month, averaged over nine years, is graphed in Figure 3.13. The nine year mean low was 71 percent of the nine year mean high which is equivalent to a 29 percent decline in milk production during the dry season. The decline in milk production during the dry season can also be calculated from the data given in Table 3.4. In Conceição milk production during the dry season declined to 89 percent of the wet season milk production; in Três Corações, to 71 percent of the wet season milk production; and in the Phase II communities, to 69 percent of the wet season production. It appears that the percentage drop in milk production which was based on the Phase 2.8 data does not agree with the drop in milk production which was based on the data collected from the milk processing plant. The reason seems to be that Conceição had several large dairy farms which had only a small drop in milk production during the dry season but which did not sell their milk to the particular milk processing plant from which the author collected his milk production figures. Of the 97 farmers who were interviewed in Conceição, 32 reported that they were selling their milk to this particular milk processing plant. These 32 farms averaged 135 liters per day during the wet season and 102 liters per day during the dry season. These averages are lower than the averages given in Table 3.4. Thus, for these 32 farmers, dry season milk production fell off to 76

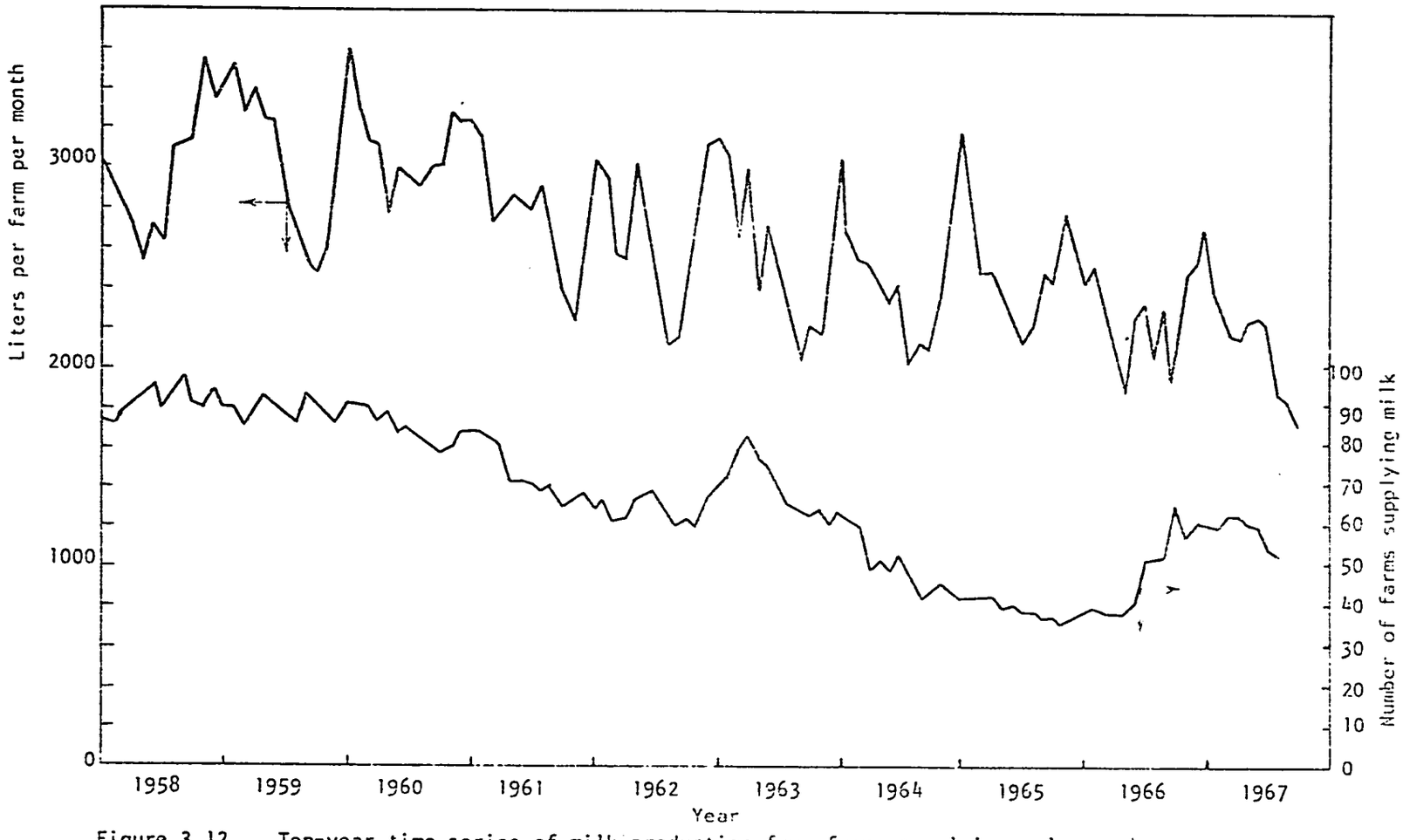

Figure 3.12 Ten-year time series of milk production from farms supplying a large cheese processor in Conceição do Rio Verde, 1958-1967.

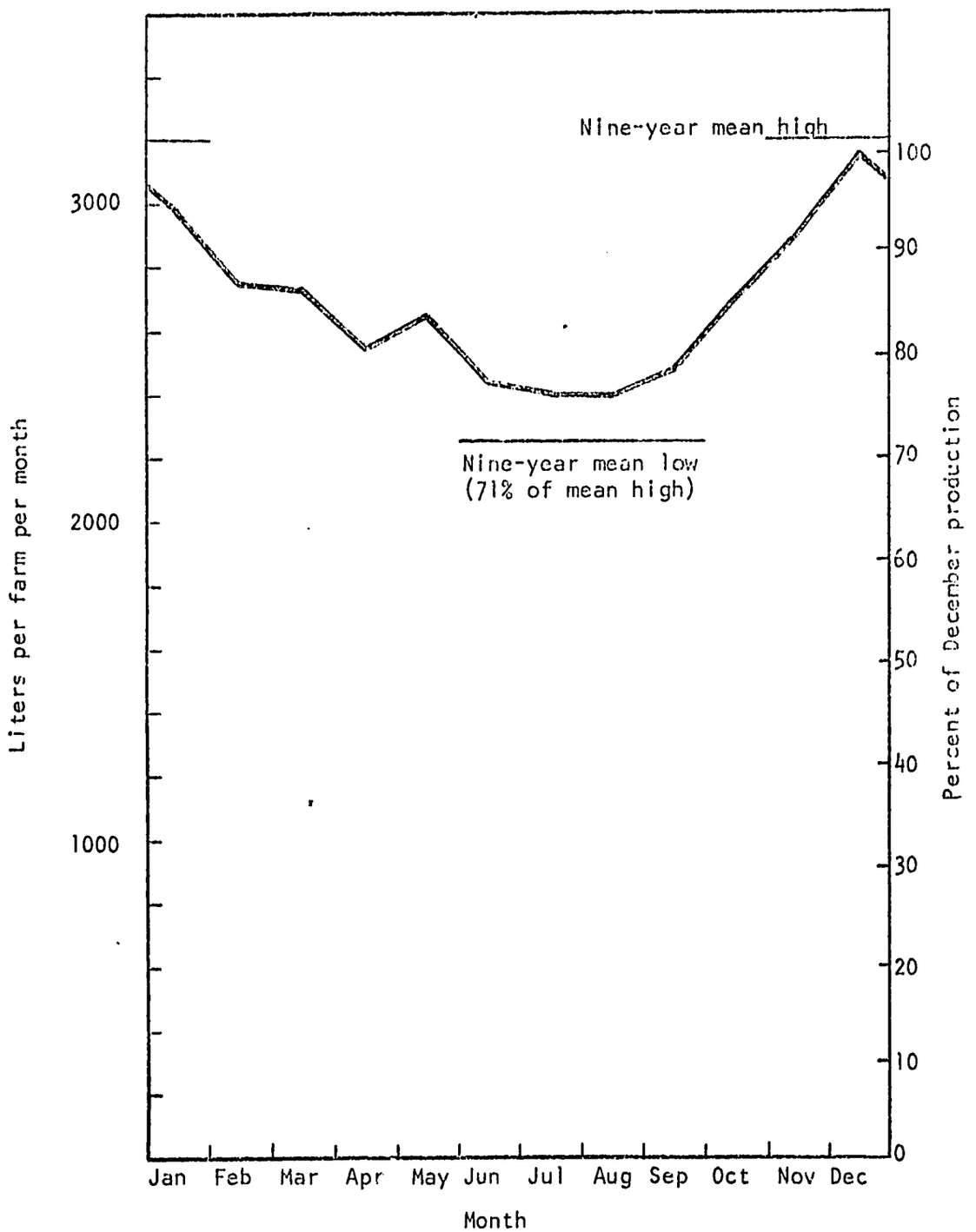

Figure 3.13 Nine-year monthly average of milk production from farms supplying a large cheese processor in Conceição do Rio Verde, 1958-1966.

percent of the wet season milk production. This later figure is closer to the drop in milk production calculated from the data for milk production of the milk processing plant. As compared to the large sample, these 32 farmers showed no significant differences in terms of their adoption of the various innovations. Thus, in spite of the conflicting evidence, one concludes that some dairy farmers in Conceição have made some progress toward smoothing out the dips and peaks which occur in milk production during the dry and wet seasons.

Although the farmers in Conceição have not succeeded in completely leveling milk production during the year, they have demonstrated higher average yearly milk production per cow than the dairy farmers in the Phase II communities. As reported in Table 3.4 the average milk production per cow per year in Conceição is 1240 liters as compared to 1180 liters in Três Corações and 790 liters in the Phase II communities. Thus the average cow in Conceição produces 57 percent more milk per year than does the average cow in the Phase II communities. Part of this higher productivity is explained by the fact that the average cow in Conceição lactates approximately 245 days out of the year, 17 percent longer than does the average cow in the Phase II communities, which lactates 210 days out of the year. Therefore the additional productivity of the cows in Conceição must be attributed to the greater use of improved dairy practices.

Further evidence that the adoption of improved dairy practices has contributed to increased milk production (at least for some of the farmers) comes from the Phase 2.8 data. When the dairy farmers in Conceição were asked whether they thought that the average milk production per cow had increased, remained the same, or decreased during the previous

two years, 48 percent thought that it had increased, 35 percent thought that it had remained the same, and 17 percent thought that it had decreased. These figures suggest that there has been at least some overall increase in milk productivity during the last two years.

CHAPTER IV

SINDI 2: EXPERIMENTAL SIMULATION RUNS

SINDI 2, a general diffusion simulation model, was applied to the diffusion of silos among the dairy farmers in Conceição do Rio Verde. This chapter discusses (a) the procedures which were used to specify the values of the parameters, attributes, and exogeneous variables required for the simulation runs; (b) the "best-fit" solution resulting from these runs and the values of the tuning parameters associated with that solution; (c) results of a series of sensitivity checking runs; (d) a "what if" run to see the effect of doubling the quantity of mass media messages about silos; and (e) an attempt to predict diffusion of forage grass plots using the same tuning parameter values as were used in the "best-fit" silo run.

The decision to simulate silo diffusion for most of the experimental runs was made for several reasons. First, content analysis of the mass media to determine the frequency of innovation messages was carried out for only four of the thirteen innovations for which time-of-adoption data had been collected during the field interviewing. This narrowed the field to four innovations: silo, forage grass plot, mineral salts, and tick spray. Tick spray was eliminated as a choice for two reasons: first, the innovation had been diffusing for a relatively long time -- 10 percent reported first hearing about it on their fathers' farms and 40 percent were using the innovation in 1957; second, some

of the largest farmers said that they were not using the innovation because a bath application was better than using a spray applicator. The question concerning tick spray was poorly worded. Instead of referring to the method of application, in this case spray, the questionaire should have referred to the use of tick pesticide in general. The diffusion of mineral salts was also eliminated as a process to be simulated, first because mineral salts appeared to have been diffusing for quite a few years -- 8 percent of the farmers had learned about mineral salts on their fathers' farms and 30 percent were using the innovation in 1957; second, a relatively high percentage of the farmers (35 percent) reported that commercial agents had been the most influential source. SINDI 2 did not have provisions for simulating influence from external commercial agents or extension agents. This narrowed the field to a choice between simulating the diffusion of silos and the diffusion of forage grass plots, both of which were moderately similar in terms of the length of time that they had been diffusing.

The choice to simulate the diffusion of silos was made because the adoption times for silos exhibited a much higher multiple correlation with various independent variables ($R = 0.78$) than did the adoption times for forage grass plots ($R = 0.53$). Part of the reason for the difference in the multiple correlation coefficients may have been that the time-of-adoption measure was more reliable in the case of silos than in the case of forage grass plots. When the author returned to the research site for further field observation after the formal interviewing had been concluded, he learned that some of the farmers condsidered sugar cane to be a forage grass. Many farmers had been using sugar cane for a number of years as a feed supplement during the dry season.

Unfortunately, the Phase 2.8 questionnaire did not make it clear that the term "forage grass" was meant to refer to the variety of special grasses (e.g., Pangola, Napier, Guatemala, etc.) which had been developed especially for forage. Consequently, some farmers may have confused the adoption of forage grass with the adoption of sugar cane; or else, the exact transition date from sugar cane to forage grass may have been difficult to remember because the two practices are so similar. Also, it may have been easier to remember the adoption date for a silo than the adoption date for a forage grass plot simply because the construction of a silo represented a much larger capital investment for most farmers than the planting of a forage grass plot. Whatever the reasons, the point is that the adoption of forage grass did not correlate nearly as well with a number of independent variables as did the adoption of the silo. Thus the silo diffusion was chosen as the process to be simulated initially. Forage grass diffusion was simulated in a follow-up series of runs using parameters that had been evaluated in silo diffusion runs.

Input Data for the Simulation of Silo Diffusion

There are two main classes of variables in a simulation model: externally defined variables (and parameters) and internally determined variables. The values of the externally defined variables must be specified by the researcher and are independent of the processing of the model during any given simulation run. SINDI 2 has four types of externally defined variables and parameters: sizing parameters, fixed attributes of entities, exogeneous variables, and tuning parameters.

Sizing parameters specify the population size of each entity type

included in the simulation model. These parameters "dimension" the structure of the simulation model. They are the arguments of the attributes and state variables which appear in the DIMENSION statements or in COMMON statements, which serve to dimension and/or reserve common blocks for the arrays of FORTRAN programs. Examples would be the total number of simulated individuals and total number of mass media channels.

Fixed entity attributes refer to the characteristics of entities which the researcher has specified should remain constant during the course of a simulation run but which can affect how the entities themselves interact during the simulation run. Examples might include sex, socio-economic status, and educational background of a simulated individual.

The exogeneous variables usually refer to inputs to the model which change over time independently of the behavior of the model's internally determined variables. These changes in the values of the exogeneous variables must be specified by the researcher. In SINDI 2 the quantity of innovation information carried by each mass media channel is treated as an exogeneous variable.

Finally, the tuning parameters are the empirical constants which appear in the various equations or relationships between the variables of the model. An example from SINDI 2 is CMAGNW, a parameter in the relationship which specifies the amount of influence on an individual resulting from his exposure to a quantity of innovation information carried by the print media.

Internally determined variables are also referred to as "state" or "status" variables. These are the variables of a model which change

as a result of processing the model over time. State variables which the researcher considers to represent the "output" of the system he is modeling are sometimes called "endogeneous" variables. An example of an endogeneous state variable in SINDI 2 is ADOPTR which has a value of 1.0 or 0.0 depending onwhether the individual is an adopter of the innovation or not. At the beginning of a simulation run each state variable in a model must be initialized to some value. In SINDI 2 the state variables are initialized in statements A-30 to A-46 of the FORTRAN program.

Model sizing parameters

The model sizing parameters for SINDI 2 include the number of time periods ineach simulation run, the number of time periods per year, the number of print media channels, the number of electronic media channels the number of local organizations, the number of individual subjects in the simulated population, and the number of sociometric dyads among the individual subjects.

Each simulation run lasted 36 time periods. A time period was set equal to six months. A six-month time period was considered to be an adequate increment since the empirical data for adoption times was collected in terms of year of adoption. The starting time of the simulation was set at the beginning of 1957, and thus the simulation ran until the end of 1974, or a simulated time period of 18 years.

A total of 12 magazine and newspaper channels were included in the simulation. These included the first 7 magazines listed in Table 3.12 and all five newspaper channels listed in Table 3.10. The field research indicated that only one radio program, the Farmer's Hour,

carried any significant amount of information about dairy innovations. This was the only electronic channel included in the simulation. The local farm cooperative was the only local organization included in the simulation.

A total of 88 individuals were included in the simulation, even though most of the empirical data reported in Chapter III were based on an N of 97 for Conceição do Rio Verde. The criterion for selecting the individuals to be included in the simulation was that they were members of the community through which the innovation was diffusing. Again, a community is defined as a group of individuals who interact more frequently among themselves than with outsiders. Thus, dropped from the simulated population were those individuals who named more than half their sociometric choices outside the final group of 88 individuals making up the simulation community and who in turn were not named by more than one other individual within the community.

The final sizing parameter specified for the standard simulation runs was the number of sociometric choice dyads existing in the simulated population. In this case, the 88 individuals included in the simulation made a total of 426 nominations for either community opinion leaders or specific discussion partners. Thirty of these nominations, usually for opinion leaders, included individuals with whom the respondents making the nominations never discussed matters related to dairy farming. Dyads involving these people were eliminated from the simulation with no effect on the outcome of a simulation run. This left 396 dyadic relationships with a greater-than-zero discussion probability, at least as perceived by the "namer." Of these, 72 dyadic relationships were with individuals not included in the simulated population of 88.

SINDI 2 does not have provision for modeling the flow of influence from individuals outside the population. Thus, these 72 dyads (18.2 percent of the total 396 dyads) could not be included, and the number of dyads included in the simulation was set equal to 324 (396 minus 72). The distribution of the 324 nominations to individuals within the simulated population and the distribution of the 72 nominations for individuals outside the simulated population are summarized in Table 4.1. Table 4.2 contains a detailed summary of the number of sociometric nominations each of the simulated individuals received. This latter information may be used in conjunction with the detailed summary of simulated output which appears later in the chapter.

A further word must be said about the sources of interpersonal influence that were outside the simulated population. The research plan had called for interviews with a complete census of the dairy farmers living in Conceição. Twenty-eight of the 41 farmers who received nominations but were not interviewed lived within the township boundaries but were not included in the simulated population; the remaining 13 farmers owned farms outside the township boundaries. It was known at the time of the interviewing that there were approximately 150 dairy farmers living in Conceição. Resources permitted interviewing those individuals living closest to the town center. Thus some of the 28 farmers not interviewed may have lived in the outlying areas of the township (the northern area was about a two hours' jeep ride from the township center). Had a second round of interviewing been possible, a special effort would have been made to interview those individuals receiving two or more sociometric choices. It was learned during the field observation that the farmer who received the eight sociometric choices had retired from dairy farming within the year and had given his farm to his sons. There was one other important

TABLE 4.1 Distribution of Sociometric Nominations by Farmers in Conceição do Rio Verde

The right-hand two columns are frequency distributions. The figures represent the number of farmers included in the simulated population and the number of farmers outside the simulated population who received the number of nominations specified in the left-hand column.

Nominations received	Simulated population N = 88	Others nominated N = 41
0	29	-
1	16	26
2	18	8
3	5	4
4	5	1
5	5	-
6	1	1
7	-	-
8	-	1
9	-	-
10	1	-
12	1	-
13	1	-
14	1	-
15	1	-
21	1	-
26	1	-
41	1	-
54	1	-
Total nominations received	324	72

- Represents zero.

influential individual (Number 652) in this group of interviewed farmers receiving nominations. Although this farmer received only one nomination as a current discussion partner on dairy farming matters, he received twelve nominations from respondents in Conceição (N = 97) as a specific first source of information about silos and six nominations as the most influential source in decisions to adopt silos. No other individual received anywhere near as many nominations as an opinion leader for the specific four innovations for which this data was secured. In his case

TABLE 4.2 Sociometric Choices Received by Respondents in Conceição do Rio Verde

Twenty-nine of the 88 respondents who were included in the simulated population received no sociometric choices and are not listed below. Sociometric choices include nominations as opinion leaders and/or discussion partners.

Respondent number	Sociometric choices received	Respondent number	Sociometric choices received
506	14	544	4
507	2	549	3
508	2	550	2
509	5	552	4
510	1	553	1
512	1	554	4
513	1	555	3
516	1	556	2
517	6	557	2
518	1	560	1
519	1	561	21
523	3	562	41
524	5	564	54
525	2	565	5
526	26	566	1
527	3	567	4
528	4	571	2
530	3	572	2
531	13	575	15
532	1	579	2
533	1	580	12
534	2	585	2
535	5	586	2
536	2	589	2
538	1	590	2
539	1	596	10
540	1	597	2
541	1	598	2
542	2	601	5
543	1		

it was learned that he had retired from dairy farming five years before (1962) and had divided his very large farm among his two sons and two sons-in-law, each of whom received a fair number of general sociometric nominations himself. The fact that he was no longer operating a dairy

farm probably accounted for his receiving only one nomination as a current discussion partner.

In summary then, there are three types of influential individuals who were not included in the simulated population: first, individuals who were influential members of the community during an earlier period but who were no longer influential at the time of data collection because they had retired, moved away, or died; second, individuals who were currently influential members of the community at the time of data collection but who were not interviewed and thus were not included in the simulated population; and third, members of other communities who from time to time influenced members of the simulated community. It is important to remember these omissions of interpersonal influence when considering the validity of the simulation model.

Attribute values for sociometric dyads

Associated with each sociometric dyad in SINDI 2 are four attributes: the identification code of the "namer"; the identification code of the "named"; the daily probability of a discussion taking place between them about work-related matters; and the credibility of the person named. Chapter III contains wording of the sociometric questions used to obtain a list of opinion leaders and discussion partners for each respondent, the frequency of discussion with each partner, and his credibility. The following response categories and their associated daily probabilities of discussion were used to code the responses to the question about frequency of discussion:

Response category	Daily probability of discussion
Never.	0.000
1-3 times per year	0.005
4-7 times per year	0.015
8-11 times per year	0.020
1 time per month	0.030
2-3 times per month	0.080
1 time per week	0.140
2-4 times per week	0.430
5-7 times per week	0.860

Attribute values for individuals

SINDI 2 requires as input data values for the various attributes associated with each simulated individual.

Year individual entered community. SINDI 2 requires as input for each individual the time when he entered the community and the time when he started his work operation, in this case when he began dairy farming. These dates affect the running of the simulation only if either occurred after the starting time of the simulation. The first bit of information was secured by asking the respondent: "How long have you lived in this community?" The answer was coded as the year of entry into the community. Twenty of the 88 simulated subjects had migrated into the social system after 1957, the starting time of the simulation. Ten of these individuals were "external adopters," individuals who had adopted the silo someplace outside the community and then migrated into the community bringing the use of the practice with them. SINDI 2 preset these individuals as adopters and did not allow them to begin influencing other members of the community until they had entered the community. In the cases of the remaining ten individuals who had not adopted the innovations prior to migrating into the community, SINDI 2 allowed them to be subject to influence from the mass media from the start of the simulation but did

not allow them to be influenced by interaction with members of the community until they had actually migrated into the community.

Year individual started dairy operation. The information about the time when the individual started his work operation was secured by asking: "How many years have you been a dairy farmer?" A total of 22 farmers became dairy farmers after the starting time of the simulation in 1957. Obviously, these individuals would not adopt the use of the silo until after they had become dairy farmers. SINDI 2 allowed these farmers to receive persuasive communications about adopting a silo for some specified time prior to actually starting their dairy farming operation. For these specific runs, the persuasion period was set equal to two years. It was assumed that during the persuasion period perspective dairy farmers would be looking into the various activities associated with dairy farming. Prior to this "persuasion period," information about innovations associated with a work operation in which they were not engaged would not be very salient to them and thus would not have much effect on them. SINDI 2 did not allow the farmers to adopt the innovations until after the start of their work operations even though in some cases the amount of influence received before the end of the persuasion period might have exceeded that individual's resistance factor.

Mass media exposure probabilities. SINDI 2 also requires of each individual his exposure probabilities to the various mass media channels. For the agricultural page in newspapers the individual exposure probabilities were obtained by asking the following question and assigning the probabilities to the responses as indicated:

Do you read the agricultural page in the newspapers? How frequently? (a) Estado de Minas (Belo Horizonte), (b) Correio da Manhã (Rio de Janeiro), (c) Estado de São Paulo (São Paulo), (d) Jornal do Brazil (Ric de Janeiro), (e) other newspapers.

Response category	Exposure probability
Never.	0.00
Rarely	0.05
Occasionally	0.10
One third of the issues	0.30
Half the issues	0.50
Most weeks	0.80
Each week	0.99

In the case of magazines, the individual exposure probabilities were obtained by asking:

In the past year did you read the magazines? How frequently? (a) O Ruralista, (b) Revista dos Criadores, (c) Cooperacotia, (d) Sítos e Fazendas, (e) O Dirigente Rural, (f) A Realidade Rural, (g) Seleções Agricolas, (h) Boletim da ACAR, (i) Boletim da Rastia, (j) other agricultural magazines.

Response category	Exposure probability[1]
Never.	0.0
Rarely	0.1
One third of the issues	0.3
Half of the issues	0.5
Most issues	0.7
Each issue	0.9

Meeting attendance. SINDI 2 also requires the individual probabilities of attending any given meeting of each local organization. For

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[1] The exposure probabilities associated with each response category were coded with only one digit in order to save columns on the IBM card. Hence there is a discrepancy with the probabilities for newspapers which were coded with two digits. Next time the author would keep these measures consistent with each other.

After the author had completed the field research, he came across a discussion by Corlett and Osborne (1966) on the design of items to obtain media exposure probabilities. Certain aspects of the items used in the Phase 2.8 questionnaire are close to the item design recommended by Corlett and Osborne.

this series of runs only one local organization was included in the simulation, the farm cooperative. Each respondent was asked: "How many meetings of the Cooperative did you attend last year?" A person's probability for attending any given meeting during the past year was calculated by dividing the number of meetings he reported attending by twelve, the total number of meetings assumed to have been held during the year. If the respondent reported attending more than twelve meetings, he was given a probability of 1.0.

Empirical adoption times. SINDI 2 requires as input an empirical adoption time for each subject. This allows the simulated output to be tuned to the real-world output thus providing values for the empirical constants and a partial validation of the model. The cumulative adoption curve for silo diffusion appearing in Figure 3.11 indicates that at the time of data collection in July, 1967, 65 percent of the dairy farmers in Conceição were using a silo (N = 97). The 35 percent who had not yet adopted were assigned arbitrary future adoption times based on their response to the series of questions:

> Are you familiar with the silo? Have you used a silo? If not, which of the following situations describes best your plans with respect to a silo?

Response category	Percent of farmers N = 97	Expected future year of adoption
POTENTIAL ADOPTER: Does not have a silo but plans to construct one	19	1968.5
KNOWER: Knows about a silo but has not yet decided to use one	5	1971.5
NONKNOWER: Does not know about silo	-	-
REJECTOR: Never used a silo and does not plan to construct one	11	1975.25[2]

Innovation resistance factor. SINDI 2 converts individuals from non-adopters to adopters when the cumulative influence to which they have been exposed exceeds the magnitude of their innovation resistance factor. The influence effect is an internal simulation variable which changes during the course of the simulation as a result of exposure to innovation messages carried by the mass media and as a result of interaction with adopters in the community. The innovation resistance factor, on the other hand, is an externally defined attribute of each simulated individual. It is expected that this resistance will depend on the variety of factors which an individual takes into account either consciously or unconsciously when he processes information from his environment about the innovation and decides if and when he will adopt the innovation. Lumped into this unidimensional attribute are all the factors which are likely to effect the diffusion process but which are not explicitly taken into account by the simulation model itself. That the measure is unidimensional is a major assumption in itself. Past diffusion research has shown that an individual's resistance to adopting an innovation may be a function of his demographic background (age, education, etc.), his attitudes toward change in

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[2]Assigning an adoption time to this group seems inconsistent with the group's description. However, assigning some value allows these individuals to be included in the regression analysis which predicts the resistance factor. Assignment of any value beyond 1971.5 places this group at the far end of the adoption scale and thus gives them appropriate scores relative to the other adopters in the regression analysis. The particular value of 1975.25 was chosen because simulated individuals who had not adopted by the end of the simulation run in 1975.0 were also arbitrarily assigned an adoption time of 1975.25. Thus individual subjects who were both potential real-world nonadopters (i.e. "rejectors") and simulated nonadopters would make the maximum possible contribution to the cross-product term in the correlation between simulated adoption times and real-world adoption times. This would increase the correlation coefficient which is as it should be since the simulation would have correctly predicted the real-world behavior.

general and to the specific innovation in particular, his attitude toward risk, his motivation toward making the changes in his behavior required by the adoption of the innovation, and the economic resources at his disposal. If we accept the notion of an underlying psychological trait called "resistance-to-innovating" -- or more specifically "resistance-to-adopting-X," because logically individuals have different resistances to adopting different innovations -- then the next question is how do we measure this trait. First, it is assumed that the trait is unidimensional and that individuals manifest different degrees of this trait which can be measured on a ratio scale of arbitrary units. Second, it is assumed that the variance observed in the real-world adoption times for the silo resulted from the variance in individuals' "resistance-to-adopting-X" and from the variance in the time and degree of individuals' exposure to innovation messages from both the mass media and adopters in the community. The "resistance-to-adopting-X" then is a function of a variety of variables not directly accounted for in the simulation model of the communication process. One procedure for obtaining a measure of the resistance factor is to perform a multiple regression analysis of year of silo adoption, the dependent variable, using only the independent variables postulated to be related to the resistance factor. The measure of the resistance factor should be at least to within a linear transformation of the underlying ratio scale, in the same sense that the Centigrade scale of relative temperature is a linear transformation of the Kelvin scale of absolute temperature. In other words, the communication variables, the effects of which are modeled by SINDI 2, are excluded from the multiple regression analysis. After the coefficients in the multiple regression equation have been determined, the predicted

value of the year of silo adoption for each individual is computed. This predicted value is taken as the best estimate of the resistance factor to within a linear transformation.

The multiple regression analysis was performed starting with 15 independent variables. Seventy-five subjects were included in the analysis; 22 of the 97 subjects were dropped from the multiple regression analysis because they had been dairy farmers less than ten years at the time of data collection. After a step-wise deletion of the less significant variables, six variables remained which accounted for 54 percent of the variance in the year of silo adoption. The six variables (variables 2 to 7) which contributed most significantly to the multiple regression were (2) number of dairy farm workers ($\log_{10}$), (3) daily milk production ($\log_{10}$), (4) number of lactating cows per worker, (5) income, (6) pasture area ($\log_{10}$), and (7) motivation.

"Income" was measured in terms of an ordinal scale of eight income brackets. "Motivation" is an index constructed from responses to the following two questions: "What do you plan to do in relation to dairy farming in the next two years? How important is it to you, in relation to your other plans which you have for your farms, to increase your milk production in the next two years?" The other variables are self-explanatory. The logarithmic transformation was used when it yielded a higher zero-order correlation than the untransformed variable. This generally occurs when the range of an untransformed variable extends over several magnitudes.

The zero-order correlations with the dependent variable and the beta weights, significance levels, and the fifth-order partial correlations are given for the six variables in Table 4.3. Five of the six

TABLE 4.3 Multiple Correlation Analysis of Year of Silo Adoption (N = 75[a])

The negative correlations imply that the higher a farmer scored on an independent variable then the earlier was likely to have been his year of adoption.

Var. No.	Independent variables	Zero-order correlation	Multiple correlation 1*2...7 R^2=0.54 R=0.73 Beta	Sig.	Par.	1*8...11 R^2=0.43 R=0.66 Beta	Sig.	Par.	1*2...11 R^2=0.61 R=0.78 Beta	Sig.	Par.	Multiple-partial correlation 1*2...7(8...11) R^2=0.32[b] R=0.56[b] Beta	Sig.	Par.
2	Workers (log_{10})	-0.47	0.81	0.002	0.37				0.73	0.004	0.35	0.75	0.003	0.35
3	Milk production (log_{10}) . .	-0.56	-0.86	0.003	-0.35				-0.66	0.025	-0.28	-0.70	0.021	-0.28
4	Lactating cows per worker .	-0.04	0.45	0.003	0.35				0.35	0.023	0.28	0.45	0.019	0.23
5	Income	-0.58	-0.32	0.008	-0.32				-0.26	0.035	-0.26	-0.27	0.030	-0.26
6	Pasture area (log_{10}) . . .	-0.51	-0.36	0.011	-0.30				-0.33	0.017	-0.29	-0.38	0.014	-0.29
7	Motivation	-0.40	-0.20	0.024	-0.27				-0.17	0.055	-0.24	-0.21	0.048	-0.24
8	Agricultural pages (in newspapers) read per month	-0.59				-0.40	<0.001	-0.41	-0.26	0.009	-0.32			
9	Agricultural magazines read per month	-0.50				-0.25	0.018	-0.28	-0.10	0.357	-0.11			
10	Cooperative meetings attended in past year . .	-0.34				-0.12	0.227	-0.14	0.02	0.835	0.02			
11	Agricultural radio programs listened to per week	-0.30				-0.10	0.283	-0.13	-0.08	0.333	-0.12			

[a]Excludes 22 respondents who had been dairy farmers less than ten years.

[b]Between residuals.

variables have significant zero-order correlations in the expected direction. Generally, the correlations indicate that the larger the farm operation as measured by variables 2, 3, 5 and 6 and the higher the farmer's motivation as measured by variable 7, then the earlier was his year of silo adoption or, in other words, the lower his resistance-to-adopting the silo. Variable 4, lactating cows per worker, did not show a significant zero-order correlation with the dependent variable.

In the multiple correlation analysis the situation changes somewhat. Surprisingly there is now a very strong positive partial correlation between the number of dairy farm workers and the year of silo adoption. This suggests that when the other variables which serve as indices for the scale of farm operations have been taken into account, merely having relatively more workers around the farm indicates a traditional outlook on farming which inhibits innovation. Another shift from the zero-order case is that variable 4, the number of lactating cows per worker, also shows a strong, positive correlation with year of silo adoption. This makes sense in that the adoption of a silo requires additional labor to harvest, prepare, and distribute the silage to the feed troughs during the dry season (see Table 3.6). Thus the more dairy cows that the average worker must tend to, the more hard pressed he would be to take on the additional chores of silage preparation and distribution. A farm with a relatively high number of cows per worker indicates a labor deficiency, a situation which is likely to make the farm owner more resistant to adopting a practice requiring additional labor.

The next step toward arriving at a value for each individual's resistance factor using the multiple regression equation is to predict

the year of silo adoption for the 88 subjects to be included in the simulated population. This predicted value is denoted as REGRM, which stands for the REGression Resistance factor based on a straight Multiple correlation. The regression resistance factor is considered to be a raw resistance factor measured on an interval scale which in itself is a linear transformation of an underlying "resistance-to-adopting-X" factor measured on a ratio scale.

However the assumption that a straight multiple regression analysis can yield the raw resistance factor requires closer scrutiny, because the 54 percent of variance in the dependent variable explained by the six attitudinal-economic variables may not be "pure." In other words, there may be other variables, in particular communication variables excluded from the multiple correlation, which are correlated with the six attitudinal-economic variables and thus may be contributing to the variance explained.

In particular, a multiple correlation analysis which was performed with four communication variables, the effects of which were directly handled in the SINDI 2 model, accounted for 43 percent of the variance in the year of silo adoption. The four communication variables were (8) agricultural pages (in newspapers) read per month, (9) agricultural magazines read per month, (10) cooperative meetings attended in the past year, and (11) agricultural radio programs listened to per week. It was not possible to include a variable which was an index of the interpersonal communication with adopters, one of the more important communication processes modeled by SINDI 2. The beta weights, significance levels, and partial correlation coefficients for the multiple correlation (1*8...11) are reported in Table 4.3. The partial correlations are all

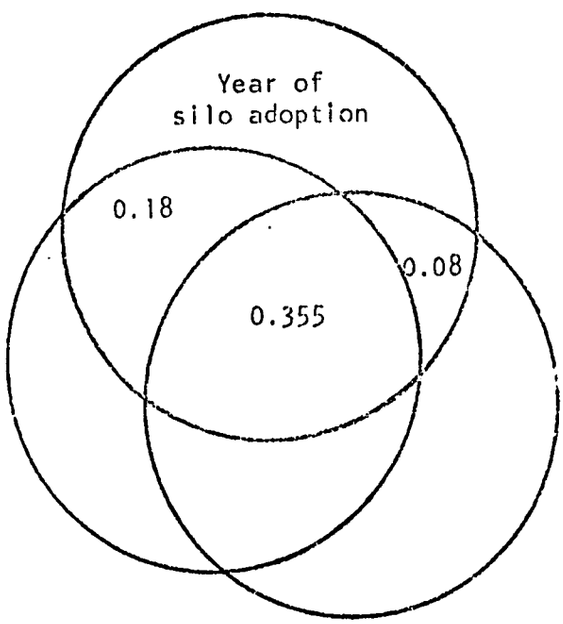
in the expected direction, i.e., the greater the exposure to sources of innovation information, the earlier the year of silo adoption, but not necessarily the lower the resistance-to-innovating. In fact, it is being postulated that variables 8 to 11 are measures of the flows of information and influence to the individual, a process independent of his innovation decision process. (As a first approximation, the effect of the filtering processes of selective exposure, selective perception, and selective retention, which would be assumed to depend on a person's resistance-to-innovating, are ignored.) An individual's resistance-to-innovating factor, which is postulated to be a function of variables 2 to 7, affects this latter process.

When a multiple correlation was performed using all 10 variables, 61 percent of the variance in the year of silo adoption was explained (see Table 4.3). Figure 4.1 shows that 35.5 percent of the variance explained in the dependent variable is common to both the attitudinal-economic variables and the communication variables. This is not surprising since, for example, farmers with large incomes are more likely to be readers of the print media than are farmers with smaller incomes. The attitudinal-economic variables acting alone explain 18 percent of the variance while the communication variables acting alone explain 8 percent of the variance. Both sets of variables "work together" to account for the remaining 35.5 percent of the variance explained.

This common variance weakens the validity of the procedure outlined above of placing individuals along an interval scale using a straight multiple regression prediction equation. Since it cannot be assumed that 54 percent of the variance is explained solely by the attitudinal-

Figure 4.1

Multiple Correlation: Variance Explained for the Dependent Variable -- Year of Silo Adoption



Attitudinal and economic variables

Workers ($\log_{10}$) (+)

Milk production ($\log_{10}$) (-)

Lactating cows per worker (+)

Income (-)

Pasture area ($\log_{10}$) (-)

Motivation (-)

Communication variables

Agricultural pages (in newspapers) read per month (-)

Agricultural magazines read per month (-)

Cooperative meetings attended in past year (-)

Agricultural radio programs listened to per week (-)

economic variables, it cannot be assumed that these variables are contributing solely to an underlying resistance factor. It may be, for example, that high income allows the farmer to subscribe for and read more agricultural magazines resulting in his exposure to a higher volume of persuasive messages than the low income farmer. It may not simply be a case that high income gives him the cushion of resources to accept the risk of being an early adopter of a new farming method. Both explanations probably play a role in the real-world process. This suggests that a procedure must be found to partition the 35.5 percent common variance between the attitudinal-economic variables and the communication variables. But how can this be done? There is no theoretical basis for making such a partition. The most logical basis seemed to be to partition the common variance proportional to the ratio of the purely explained variances, i.e. 0.18:0.08.

The following procedure was adopted in order to do this. First, a multiple-partial correlation analysis was performed in order to partial out the entire contribution of the communication variables to both the variance of the dependent variable and the variances of the attitudinal-economic variables (see Blalock, 1960, p. 350). Then a multiple correlation analysis of the residuals of each of the six independent variables was utilized to arrive at predicted values for the dependent variable residuals. These predicted values were designated as REGRMP (raw REGression Resistance predicted from Multiple-Partial correlation). As indicated in Table 4.3, the zero-order correlation between the multiple-partial regression resistance (REGRMP) and the residual of silo adoption yields an R of 0.56 and an R^2 of 0.32. Thus the variance explained in a zero-order correlation between the multiple-partial regression

resistance (REGRMP) and the original scores for year of silo adoption would be 0.18. This result is calculated from the areas shown in Figure 4.1: 0.32:1.00 = 0.18:0.565. The value of 0.565 is the variance remaining in the dependent variable after removal of the contribution from the communication variables.

The next step in the procedure was to linearly transform the multiple-partial regression resistance (REGRMP) to a new distribution, TREGRMP, having the same mean and variance as REGRM. The transformed multiple-partial regression resistance (TREGRMP) and the straight regression resistance (REGRM) accounted for 18.0 and 53.5 percent of the variance in year of silo adoption respectively. These two distributions provided the basis for constructing a new distribution, the raw resistance distribution (REGRMIX), which behaved as if it partitioned the variance common to the attitudinal-economic variables and the communication variables in the desired ratio of 0.18:0.08. Thus the raw resistance distribution (REGRMIX) should account for 42.7 percent of the variance in silo adoption (see Table 4.4). It can be shown if two distributions, M and MP, with the same means and variances are averaged together in the ratio f:(1 - f) to form a third distribution, MIX, then the correlation of MIX with a fourth distribution Y will be given as:

$$r_{MIX} = (1 - f) \cdot r_{MP} + f \cdot r_{M}$$

Solving for f in the formula above yields:

$$f = \frac{r_{MIX} - r_{MP}}{r_{M} - r_{MP}}$$

These three correlation coefficients needed to calculate the mix

fraction, f, are given in Table 4.4. Solving for f yielded a value of 0.75. Therefore, in computing the raw resistance distribution (REGRMIX), the weighting values for the transformed multiple-partial regression distribution (TREGRMP) and the straight regression resistance (REGRM) were 0.25 and 0.75 respectively. The resulting distribution REGRMIX was used as the raw regression resistance factor required for each simulated individual in SINDI 2.

It should also be noted that Tables 4.3 and 4.4 include the multiple regression analysis of year of silo adoption when all 11 independent variables are included in the analysis. This is a standard type of analysis which is reported in the diffusion literature. This "linear regression model of innovation diffusion" (LRMID) takes into account the important attitudinal, economic, and communication variables in seeking to explain the variance in the dependent variable, year of silo adoption. It is this linear regression model of innovation diffusion against which the performance of SINDI 2 can be measured later in our discussion.

Table 4.5 summarizes how the 97 respondents were utilized in both the multiple correlation analysis and as simulated subjects.

Exogeneous variables: mass media messages

Subroutine INPUTM reads the "quantity" of innovation messages carried by each of the mass media channels. Quantity of information was measured in square inches of print for the print media and in minutes of program time for the electronic media. These in themselves are very crude measures. They do not take into account a host of other message variables that are known to be related to persuasiveness of a message.

TABLE 4.4 Explained Variances in the Year of Silo Adoption by the Linear Regression Model of Innovation Diffusion (LRMID), the Multiple Regression Distribution (REGRM), the Raw Resistance Distribution (REGRMIX), and the Transformed Multiple-Partial Regression Distribution (TREGRMP) for N of 75

Form of multiple correlation	Distribution	Variance explained	Correlation coefficient
		r^2	r
		1.000	1.000
1*2...11	LRMID	0.613	0.783
1*2...7	REGRM	0.536	0.732
Combined	REGRMIX	0.427	0.654
1*2...7(8...11)	TREGRMP	0.180	0.424
		0.000	0.000

Nevertheless these measures were considered to be at about the same level of detail as other measures included in the simulation. Ideally, the way to collect the data needed to specify the message inputs for the simulation would have been to content analyze all 13 of the mass media channels for the past ten years in order to measure the quantity of information

TABLE 4.5 Utilization of Respondents in the Standard Simulation Runs for the Diffusion of Silos versus Utilization of Respondents in the Multiple Regression Analysis Predicting Resistance to Silo Adoption

Utilization of Respondents in Multiple Regression Analysis	Used as fully simulated individuals	Preset as "innovators"	Preset as "external adopters"	Dropped from simulation because respondents were not part of community communication network	Totals
Included in regression analysis	56	4	6	9	75
Dropped from analysis because respondents had been dairy farmers less than ten years	15	-	4	-	19
Dropped from regression analysis because respondents adopted prior to 1952 (i.e. they were deviant cases)	-	2	-	-	2
Dropped because respondents gave no response on year of adoption	1	-	-	-	1
Total	72	6	10	9	97

- Represents zero.

concerning the silo which was carried by each channel. The author did not have the resources to carry out this task. However, in the time available it was possible to locate and content analyze 21 issues of Revista dos Criadores, 17 issues of Coopercotia, 26 issues of O Dirigente Rural, and 28 issues of A Realidade Rural. The summary of the results of this content analysis appears in Table 4.6. A summary of the message

input data for the simulation runs appears in Table 4.7. Empirical values (underlined) were entered for Revista dos Criadores, Coopercotia, O Dirigente Rural, and A Realidade Rural for those periods in which data from the content analysis were available. Otherwise, values based on the average-per-period values in the last column of Table 4.6 were used as input data. The values were modified by a monotonically increasing step function under the assumption that the media probably were carrying increasingly more information about silos as time went by. Sítios e Fazendas and Seleções Agricolas were considered to give about the same emphasis to dairy farming as did Coopercotia, a magazine less oriented to dairy farming than Revista dos Criadores, O Dirigente Rural, and A Realidade Rural. Thus Sítios e Fazendas and Seleções Agricolas were assigned approximately the same input values as Coopercotia.

O Ruralista is a biweekly agricultural newspaper which started publication in 1963. The one issue which the author saw had eight pages. The agricultural magazines cited above averaged 70 to 100 pages per issue. In one sense, O Ruralista is similar to the special agricultural sections carried by some of the metropolitan newspapers. Unfortunately, the author did not have time to locate and content analyze these newspaper channels, and thus the input values for the messages carried by these channels had to be rather arbitrarily assigned. The author had little information about the extent of the agricultural coverage by the four main newspapers most frequently read by the farmers in Conceição. He did see one agricultural supplement of the Estado de Minas published in Belo Horizonte. It also contained eight pages devoted to agricultural matters. It was reported by one of the interviewers that one of the newspapers from Rio de Janeiro did not

TABLE 4.6 Quantity of Information about Silo Usage appearing in Four Agricultural Magazines

Magazine	Number of issues analyzed	Average quantity per issue (square inches)	Average quantity of information per six-month period (square inches)
Revista dos Criadores . .	21	54	324
Coopercotia	17	8	45
O Dirigente Rural	26	22	130
A Realidade Rural	28	28	140[a]

[a]A Realidade Rural averaged only 5 issues per six-month period; the other three averaged 6 issues per period.

have an agricultural section as such. Only an economic-business section which also carried information on agricultural matters. The author was unable to verify this.

In spite of these uncertainties, there is some evidence that the agricultural pages in newspapers were carrying information about silos. The data in Table 3.7 indicate that almost as many farmers (46 percent) reported obtaining information about silos from newspapers as reported obtaining information from magazines (49 percent). Also readership of the agricultural pages correlated even more strongly (-0.59) with the year of silo adoption than did agricultural magazine readership (-0.50). This was particularly true in the multiple correlations (see Table 4.3). These correlations do not necessarily prove that the newspaper channels were carrying innovation information which influenced farmers to adopt these innovations. It could be that newspaper readership is an index of a complex of intellectual and motivational characteristics

TABLE 4.7 Quantity of Actual and Estimated Information about Silos Carried by the Print Media for Each Simulated Time Period

In square inches of space devoted to silos. The underlined figures represent empirical data gathered by means of a content analysis of the channels. The remaining figures are estimates and extrapolations.

Year	Revista dos Criadores[a]	Coopercotia[a]	O Dirigente Rural[a]	A Realidade Rural[a]	Sítios e Fazendas and Seleções Agrícolas[a]	O Ruralista[b]	Newspapers[c]
1957	300	20	100	0	25	0	140
	300	20	100	0	25	0	140
1958	300	20	110	50	25	0	140
	300	20	110	50	25	0	140
1959	300	20	110	75	25	0	140
	300	20	110	75	25	0	140
1960	300	30	120	100	25	0	140
	300	30	120	100	25	0	140
1961	300	30	120	120	25	0	140
	300	30	120	120	25	0	140
1962	325	30	120	130	30	0	150
	325	30	120	130	30	0	150
1963	0	30	130	140	30	80	150
	480	30	130	375	30	80	150
1964	325	40	130	90	30	90	150
	325	40	130	70	30	90	150
1965	172	0	193	230	30	100	150
	325	138	0	37	30	100	150
1966	325	40	172	0	30	110	150
	325	40	0	0	30	110	150
1967	485	10	194	140	35	120	160
	325	40	0	0	35	120	160
1968	325	40	130	140	35	120	160
	325	40	130	140	35	120	160
1969	325	40	130	140	35	120	160
	325	40	130	140	35	120	160
1970	325	40	130	140	35	120	160
	325	40	130	140	35	120	160
1971	325	40	130	140	35	120	160
	325	40	130	140	35	120	160
1972	350	40	140	160	40	120	170
	350	40	140	160	40	120	170
1973	350	40	140	160	40	120	170
	350	40	140	160	40	120	170
1974	350	40	140	160	40	120	170
	350	40	140	160	40	120	170

[a]Monthly magazine. [b]Biweekly agricultural newspaper started in 1963.
[c]Agricultural pages in newspapers.

that are associated with innovativeness. Nevertheless, the correlations do not damage the case that the newspaper channels probably were carrying innovation information. On this basis, then, each newspaper channel was assigned a message input value equivalent to the average message input value for the four magazine channels: 160 square inches of information per six-month period. O Ruralista, being biweekly, was assigned somewhat lower message input values.

The data available on information carried by the one agricultural radio program Farmer's Hour was also very sketchy. The program manager reported that the station did not save old radio scripts. He estimated that approximately 70 short advisories on the benefits of using a silo had been made during the last year. The sample script included in Appendix A indicates that such an advisory might last approximately one-half minute. Thus the quantity of information that was broadcast over the Farmer's Hour during the first six-month time period of 1967 was estimated to be about 20 minutes worth. The rest of the time periods were assigned values which ranged from 10 minutes in 1957 to 25 minutes in 1974.

Exogeneous variables: meetings of local organizations

SINDI 2 also required as input the number of meetings held by each local organization during a given time period. This data was not specifically obtained during the research. Furthermore, there were complications because the general agricultural cooperative in Conceição do Rio Verde had been disbanded and a new dairy cooperative had been formed. These events had taken place within the year prior to the collection of the field data (in 1966). The Phase 2.8 questionnaire

did make a distinction between the old and the new cooperative in asking about attendance at cooperative meetings. However, for purposes of the simulation the old cooperative and the new cooperative were treated as one continuous organization. When asked about attendance at the cooperative meetings during the past year, four respondents reported attendance at more than 12 meetings. However, some of the meetings may have been meetings held among a few members for the purpose of planning the new cooperative. An arbitrary value of six meetings per period was chosen for ten periods surrounding the time of the formation of the new cooperative and four meetings per year for the rest of the time periods.

Tuning parameters

There are eight "tuning" parameters included in the simulation model. These can also be thought of as the empirical constants in the model which must be evaluated by applying the model to real-world data. In any branch of science an investigator may postulate a set of relationships about some phenomenon and then evaluate the constants in the expressions by "curve-fitting" his expressions to the real-world case.

The method for tuning the output of SINDI 2 to the real-world data was to adjust the parameters in order to obtain first the best fit between the simulated cumulative adoption curve and the real-world cumulative adoption curve (i.e. agreement at the macro or aggregate level) as measured by the Kolmogorov-Smirnov two-sample test, and second the best correlation between the simulated times of adoption and the empirical times of adoption for individual subjects (i.e. agreement at the micro level).

Two parameters, RISTMN and RISTSD, specified the shape of the "resistance-to-adopting-X" distribution, X in this case being a silo. The objective in choosing these two parameters was to transform the distribution of the raw resistance factor to the resistance factor used in the simulation. The raw resistance factor was scaled as an interval scale SINDI 2 requires that the resistance factor be scaled as a ratio scale; in other words, a resistance of 40 is assumed to be twice the resistance of 20 -- a characteristic only valid for a ratio scale. Since the units of resistance are arbitrary, the mean of the resistance distribution, RISTMN, was arbitrarily chosen to be 50. The value of the standard deviation, RISTSD, would be selected so that a few simulated individuals would have a low resistance.

It was also necessary to consider values for the four influence parameters: CMAGNW, CRADTV, CMLORG, CNEHBR. These parameters specified the degree to which an individual's resistance is overcome as a result of his exposure to units of innovation messages carried by the print media and the electronic media and to discussions with adopters encountered at meetings of local organizations and individually. The data in Tables 3.8, 3.21, and 3.22 suggested that word-of-mouth discussions seemed to be the most important influencing process in the diffusion of silos in Conceição. It was decided that the value of CNEHBR should be initially chosen so that pairwise discussions would account for approximately 75 percent of the total influence effect from all channels on the simulated population. Since print media exposure contributed strongly to the multiple regression analysis of silo adoption, it was felt that for the initial simulation run CMAGNW should be chosen so that the influence effect of the print media contributed about 20

percent of the total influence effect. Finally, the data seemed to suggest that exposure to radio programs and attendance at cooperative meetings played a less important role in the influence process. Thus it was felt that CRADTV and CMLORG should be chosen so that these two channels together accounted for only about 5 percent of the total effect. In subsequent runs the values of the influence parameters would be altered in order to obtain the best-fit set of parameters.

The final two tuning parameters, CINFLU and CINERT, are empirical constants in the relationships which express the degree to which an individual is influenced by his interaction with sociometric choice partners. CINFLU scales the raw frequency of interaction to an "effective" frequency of interaction. In a series of tuning runs CINFLU was varied from 0.0 to 1.0. CINERT determines the extent to which the influence effect from an individual's interaction with adopters among his circle of sociometric choice partners is reduced as a result of his interaction with nonadopters among his partners. In a series of simulation runs CINERT was allowed to vary from 0.0 to 0.5.

The "Best-fit" Simulation Run for Silo Diffusion

Two major criteria were used to determine the "best-fit" simulation run. First, at the aggregate level, the simulated cumulative adoption curve was compared with the real-world cumulative adoption using the Kolmogorov-Smirnov two-sample test for goodness-of-fit. Second, at the micro level, the correlation between the simulated adoption times and the real-world adoption times was examined. Since there are two criteria to be maximized, the best-fit aggregate solution and the highest correlation, it usually is not possible to find a single

solution which will satisfy both criteria. One can either choose a simulation run which will maximize one criterion while still scoring acceptably well on the other criterion and vice versa, or one can choose a simulation run which is a compromise between maximizing one or the other criterion.

In the application of SINDI 2 to the diffusion of silos among 88 dairy farmers in Conceição do Rio Verde the best-fit simulation run was selected which gave the highest correlation at the micro level while still performing satisfactorily at the aggregate level. The best-fit run was achieved with the tuning parameters set at the following values: the mean of the simulation resistance distribution (RISTMN) was set at 50 units of resistance to silo adoption while the standard deviation of this distribution (RISTSD) was set at 31 resistance units. As for the influence parameters, CMAGNW was set to 0.0071 influence units per square inch of print media; CRADTV, to 0.011 influence units per minute of the electronic media; CMLORG, to 0.0093 influence units per interaction with adopters at meetings of local organizations; and CNEHBR, to 1.12 influence units per interaction raised to the power of CINFLU. CINFLU, the power to which the raw frequency of interpersonal interaction was raised, took on a value of 0.25 (a pure number); CINERT, which determines the degree of negative influence from interaction with nonadopters also took on a value of 0.25 (a pure number).

Another important characteristic of the best-fit run was that the credibility variable ($CREDIB_{ij}$), which appears in the sociometric influence equations (A-34 and indirectly A-85), was preset to have the same value (0.82) for all sociometric interactions. This value of 0.82 represented the average of the empirical values of the ladder

ratings (divided by 10) given by the respondents for the discussion partners and opinion leaders which they named. Using the same value for the credibility variable resulted in a higher correlation at the micro level than using the empirical values given by the respondents. This result will be further discussed in the following section on sensitivity testing.

At the aggregate level Figure 4.2 presents a visual comparison between the simulated cumulative adoption curve and the real-world cumulative adoption curves.[3] Application of the Kolmogorov-Smirnov two-sample test for goodness-of-fit between the two distributions (N = 88) yielded a value of 0.62 for the probability that the two distributions came from the same population. Since the simulated adoption times of the innovators and external adopters were set by SINDI 2 to be equal to their empirical adoption times, the two "samples"

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[3]Figures 4.2, 4.5, and 4.7 were produced directly by the computer on the line printer. Each figure contains a simulated cumulative adoption curve represented by O's and an empirical adoption curve represented by X's. For those points at which the two plots coincide, only the symbol O is printed. A line was drawn through each set of symbols to represent the cumulative curve. The step-like appearance of each curve results from several factors. First, the resolution of the graph on the original computer print-out is only to one-sixth of an inch along the vertical axis and one-tenth of an inch along the horizontal axis. Second, the fact that there are 88 discrete subjects will cause discrete steps to appear in the cumulative curves. Third, the adoption times themselves can only take on certain values: the simulated data can take on mid-half-year values, e.g. 1965.25 or 1959.75, and the empirical data can take only mid-year values, e.g. 1964.50. Thus the cumulative adoption curves will only change ordinate values at these respective sets of abcissa values. Finally, those respondents who had not adopted the particular innovation by the time of data collection in July, 1967, were arbitrarily assigned future years of adoption (e.g. 1968.5, 1971.5, or 1975.25) on what they said that they planned to do. All of these factors contribute to the step-like appearance of the cumulative distribution curves. Rather than draw smooth curves through the data points, the author drew the graphs in the form of step functions because the Kolmogorov-Smirnov two-sample test and the calculation of the area between the two plots was applied to the data in this form.

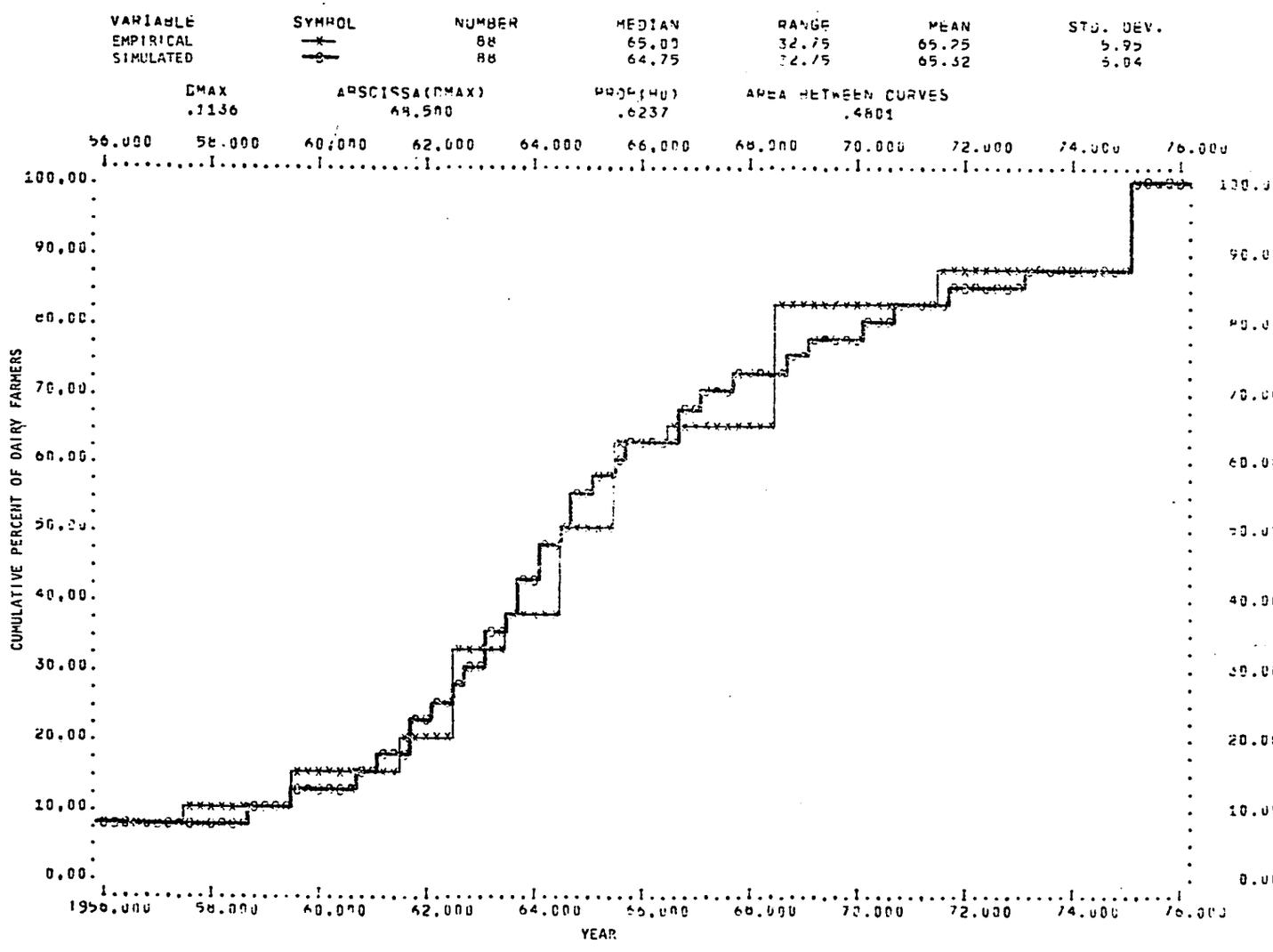

Figure 4.2 Comparison of the "best-fit" simulated cumulative adoption curve and the empirical cumulative adoption curve for silo diffusion.

were not totally independent of one another. When the innovators and external adopters were excluded from the two population "samples" (resulting in an N of 72), the corrected Kolmogorov-Smirnov probability was equal to 0.49. The uncorrected probability of 0.62 was considered acceptable because the maximum deviation between the simulated and empirical curves occurred at a value of 1968.5, the point at which 15 subjects who had not adopted by the time of data collection were arbitrarily assigned an adoption time because they indicated that they planned to adopt the innovation in the future. Visual comparison of the two curves suggests that if there had been no discontinuity in the empirical curve it probably would have been possible to achieve a better fit as measured by the Kolmogorov-Smirnov test.

At the micro level, Table 4.8 presents a comparison between the performance of SINDI 2 in predicting individual adoption times and the performance of the general linear regression model of innovation diffusion (LRMID) which predicted individual adoption times from ten independent attitudinal, economic, and communication variables (see Table 4.3). Both models explained approximately 48 percent of the variance in the empirical adoption times. For an N of 72 the 95 percent confidence limits below and above this value of the explained variance are 0.31 and 0.64. Note that SINDI 2 also performed somewhat better in predicting adoption times than did the resistance factor which was derived from a multiple partial-regression analysis based on only the attitudinal-economic variables. This is important because the resistance factor accounts for over 60 percent of the variance in the simulated output from SINDI 2; thus, it appears that SINDI 2 has added something to the predictive ability of the raw data inputs.

However, one would have expected SINDI 2 to have performed better than both resistance factor and the general linear regression model in predicting individual adoption times, because the simulation model not only took into account the variables which were included in the linear regression model but also modeled the interpersonal communication subprocess which was not taken into account by the linear regression model. One would think that the flow of information and influence through the interpersonal communication network would account for a significant part of the pattern of diffusion in the community. At this point it is not clear how much contribution SINDI 2 is making toward modeling the overall diffusion process. The sensitivity analysis which is discussed later will throw more light on this question.

TABLE 4.8 Comparison of the Micro Level Performance of SINDI 2 and the General Linear Regression Model of Innovation Diffusion (LRMID) for Predicting Individual Adoption Times in the Case of Silo Diffusion

Correlations are based on an N of 72 which excludes innovators and external adopters. "Adoption" refers to the time at which an individual subject adopted the silo.

Variables	Correlation coefficient r	Common or explained variance r^2
Best-fit simulation run by SINDI 2		
Simulated adoption x real-world adoption	0.695	0.483
Regression resistance x real-world adoption	0.681	0.464
Regression resistance x simulated adoption	0.787	0.619
Linear regression model of innovation diffusion (LRMID)		
Predicted adoption x real-world adoption	0.696	0.484

Other results from this best-fit run are worth noting. At the aggregate level, the percentage contribution from each of the four channels to the total influence effect was as follows:

Channel	Percent of total influence
Magazines and newspapers	23.6
Radio programs	1.4
Local meeting interaction	2.6
Sociometric interaction	72.4

At the micro level, a detailed summary of the simulated adoption time, community entry time and dairy operation start-up time (printed if both occurred later than 1957.0), and the distribution of influence from four channels are given in Table 4.9 for each individual subject included in the simulated population.

Sensitivity Testing

A series of runs was made to determine how the model responded to changes in the tuning parameters and other input data.

Parameters of the resistance distribution

The mean of the resistance distribution, RISTMN, had been arbitrarily set at a value of 50 resistance units. All other values of the tuning parameters were then varied in order to achieve a best-fit of the simulated output with the real-world data. Thus the value of RISTMN remained unchanged throughout the sensitivity checking.

Changing the value of the standard deviation of the resistance distribution, RISTSD, had the effect of peaking or flattening the bell-shaped frequency distribution curve of simulated adoption times. This effect is equivalent to changing the rate of the rise of the S-shaped cumulative adoption curve. During the search for the best-fit run,

TABLE 4.9 Micro-level State Variables and Attributes Associated with Each Simulated Individual during the "Best-fit" Simulation Run for Silo Diffusion

TIME PER.	EXT. ID.	SIM. ADOPT. TIME	DATA ADOPT. TIME	TIME ENTERED COM.	TIME BEGAN ADOPTN.	RESIS-TANCE	CUMULATIVE INFLUENCE: TOTAL	MAGAZ.-NEWSPR.	RADIO-TV	MEETING	NEIGHBORS
	544	42.50	42.50			47.82					
	551	51.50	51.50			32.43					
	556	52.50	52.50			33.19					
	513	52.50	52.50			33.14					
	554	54.50	54.50			19.04					
	559	55.50	55.50			-1.39					
3	538	58.25	65.50			10.49	14.87	10.44 (72.8)[a]	0.00 (0.0)[a]	.05 (.4)[a]	3.97 (26.7)[a]
4	560	58.75	64.50			4.51	5.54	5.23 (93.9)	.09 (1.6)	.29 (5.2)	0.00 (0.0)
	536	59.50	59.50	59.51		27.07					
6	579	59.75	59.50			12.54	14.96	12.93 (91.7)	.24 (3.6)	.35 (2.4)	1.83 (12.3)
7	561	60.25	65.50			19.28	17.64	17.44 (100.0)	0.00 (0.0)	0.00 (.0)	0.00 (0.0)
8	596	60.75	62.50			39.38	4.87	2.92 (59.9)	.72 (1.5)	.43 (1.5)	19.52 (38.0)
9	557	61.25	62.50			29.92	31.75	14.73 (56.4)	1.07 (3.3)	.74 (2.4)	12.47 (39.4)
9	558	61.25	62.50			30.45	35.21	23.05 (65.4)	1.02 (2.7)	1.47 (3.9)	10.58 (27.9)
9	555	61.25	64.50			30.53	34.27	23.15 (56.4)	.05 (.1)	.74 (1.9)	10.34 (41.6)
10	512	61.75	59.50			24.49	30.10	4.74 (67.1)	1.18 (3.3)	0.00 (7.0)	23.14 (59.5)
10	565	61.75	64.50			31.81	55.28	21.76 (36.1)	1.13 (2.0)	.98 (1.3)	29.45 (50.9)
10	551	61.75	59.50			48.26	51.24	37.70 (73.5)	.06 (.1)	.59 (1.2)	12.54 (9.1)
11	569	62.25	61.50	59.51	59.51	22.37	23.43	10.73 (45.8)	.06 (.3)	1.44 (6.2)	11.14 (47.6)
11	554	62.25	57.50			31.37	21.43	10.72 (50.1)	0.00 (0.0)	.17 (.8)	2.17 (9.5)
11	543	62.25	61.50			10.43	12.25	1.78 (14.5)	.07 (.5)	1.74 (14.2)	8.69 (70.5)
	537	59.50	59.50	62.51	59.51	24.37					
	564	62.50	62.50	62.51		37.21					
12	510	62.75	62.50			23.57	25.57	24.76 (49.4)	0.00 (0.0)	.43 (3.1)	1.15 (4.6)
12	564	62.75	64.50		62.51	17.15	23.53	4.07 (17.2)	.04 (.2)	.51 (2.5)	19.41 (80.1)
12	567	62.75	63.50	58.51	62.51	60.37	69.44	21.53 (33.4)	0.00 (0.0)	2.13 (3.3)	41.47 (63.4)
13	533	63.25	62.50	60.51		59.37	59.10	31.40 (56.4)	1.54 (3.0)	.20 (.3)	22.74 (41.6)
13	555	63.25	64.50	60.51	58.51	24.57	31.51	17.25 (34.5)	1.47 (4.4)	.64 (2.0)	12.25 (54.7)
13	560	63.25	57.50			40.54	54.15	27.70 (53.1)	.35 (.6)	.45 (1.0)	24.17 (44.5)
13	564	63.25	64.50			37.61	39.48	.70 (1.2)	1.65 (4.2)	2.96 (7.6)	34.54 (85.6)
	567	62.50	62.50	63.51	57.51	70.[illegible]					
	562	63.50	63.50	63.51		74.[illegible]					
14	517	63.75	63.50		63.51	21.14	26.27	12.44 (47.5)	.18 (.5)	.59 (2.5)	12.45 (49.5)
14	560	63.75	65.50			34.46	34.21	14.85 (35.6)	.12 (.6)	4.55 (5.0)	17.15 (53.6)
14	569	63.75	62.50			[illegible]	34.21	20.74 (79.0)	.35 (1.1)	2.70 ([illegible])	6.51 (19.9)
14	552	63.75	66.50			15.47	14.57	.11 (.8)	1.32 (9.8)	.51 (3.5)	10.63 (74.3)
15	562	64.25	58.50			57.45	51.43	.53 (.9)	1.03 (0.0)	.35 (.0)	51.54 (99.8)
15	560	64.25	65.50			34.18	37.47	4.92 (63.5)	0.00 (0.0)	2.70 ([illegible])	28.84 (75.5)
15	570	64.25	62.50			33.54	34.41	11.35 (29.9)	.42 (1.0)	2.73 ([illegible])	27.54 (69.0)
15	597	64.25	66.50			34.61	44.52	19.19 (43.4)	1.03 (2.3)	4.92 (11.1)	20.79 (46.7)
	535	64.50	64.50	64.51	63.51	[illegible]					
	563	64.50	64.50	64.51	62.51	[illegible]					

16	527	64,75	62,50			33,86	35,72	15,33	(42,9)	1,14	(3,2)	2,32	(6,5)	19,91	(47,5)
16	541	64,75	68,50		64,51	23,89	30,58	17,95	(58,7)	.09	(.3)	2,85	(9,3)	9,89	(31,7)
16	542	64,75	66,50			71,11	77,75	7,79	(10,0)	.12	(.1)	2,77	(3,6)	67,05	(86,3)
16	556	64,75	68,50			22,85	28,49	1,93	(6,8)	0,00	(0,0)	4,59	(16,1)	21,47	(77,1)
16	575	64,75	64,50	59,51	64,51	24,69	51,39	17,75	(34,5)	0,00	(0,0)	1,13	(2,2)	32,21	(63,3)
16	589	64,75	65,50		61,51	54,39	63,10	15,31	(24,3)	.18	(.3)	2,35	(3,7)	45,27	(72,2)
17	518	65,25	71,50			46,31	53,53	25,07	(46,8)	.25	(.5)	1,58	(3,1)	26,62	(49,5)
17	555	65,25	61,50			34,29	41,35	.45	(2,1)	1,27	(3,1)	1,15	(2,8)	38,07	(92,1)
	540	65,50	65,50	65,51		56,36									
	600	65,50	65,50	65,51	65,51	46,86									
18	565	65,75	62,50	61,51	61,51	35,70	41,34	0,00	(0,0)	0,00	(0,0)	0,70	(0,0)	41,34	(100,0)
19	553	66,25	65,50	62,51	65,51	37,37	41,54	.94	(2,2)	.25	(.6)	1,70	(3,7)	39,11	(93,4)
20	511	66,75	65,50		60,51	33,30	36,68	0,00	(0,0)	1,44	(3,9)	0,00	(0,0)	35,24	(95,1)
20	514	66,75	75,25		66,51	47,58	49,46	0,00	(0,0)	0,00	(0,0)	0,00	(0,0)	49,46	(100,0)
20	566	66,75	65,50	57,51	64,51	50,69	53,76	8,47	(15,8)	.18	(.3)	2,77	(5,1)	42,34	(78,8)
20	592	66,75	64,50			43,11	44,36	0,00	(0,0)	.15	(.4)	2,52	(5,9)	41,67	(93,9)
20	602	66,75	68,50			65,16	71,33	29,29	(41,1)	.16	(.2)	0,70	(1,0)	41,85	(58,7)
21	545	67,25	71,50			71,53	98,59	0,00	(0,0)	0,00	(0,0)	0,70	(0,7)	98,59	(100,0)
21	556	67,25	66,50		59,51	74,86	75,15	34,17	(45,5)	.17	(.2)	0,70	(0,9)	40,81	(54,3)
	532	63,50	63,50	67,51		-.99									
22	569	67,75	68,50			71,59	76,99	0,00	(0,0)	1,54	(2,4)	0,70	(,0)	75,15	(97,5)
24	519	68,75	68,50			77,39	82,12	29,99	(36,5)	.82	(1,0)	3,93	(4,8)	47,38	(57,7)
24	523	68,75	61,50			39,05	41,36	6,13	(14,8)	.41	(1,0)	2,32	(5,6)	34,82	(84,2)
24	563	68,75	66,50	65,51		60,58	66,54	0,00	(0,0)	0,00	(0,0)	2,96	(4,4)	63,58	(95,6)
24	601	68,75	68,50			58,83	59,68	24,74	(41,5)	3,92	(6,6)	2,67	(4,5)	28,35	(47,5)
25	536	69,25	68,50			99,91	100,55	25,96	(25,8)	.44	(.4)	0,70	(0,7)	74,59	(73,9)
26	539	69,75	68,50	57,51	61,51	73,43	75,27	28,44	(37,8)	3,25	(4,3)	0,00	(0,0)	43,83	(57,9)
27	516	70,25	62,50			38,01	44,54	0,00	(0,0)	2,46	(5,5)	0,00	(0,0)	42,08	(94,5)
27	571	70,25	75,25			52,85	56,36	4,45	(11,8)	.25	(.4)	1,47	(2,6)	48,17	(85,5)
28	546	70,75	75,25			50,91	51,24	0,00	(0,0)	.52	(.8)	0,00	(0,0)	50,73	(99,2)
29	502	71,25	68,50		57,51	85,19	86,51	9,48	(10,4)	2,74	(3,1)	0,00	(0,0)	76,35	(88,3)
30	549	71,75	64,50			51,86	62,61	0,00	(0,0)	.29	(.5)	5,28	(8,4)	57,04	(91,1)
31	520	72,25	63,50			63,93	69,59	2,26	(3,3)	3,02	(4,3)	0,00	(0,0)	64,30	(92,4)
33	503	73,25	68,50		57,51	70,23	73,02	0,00	(0,0)	0,00	(0,0)	0,00	(0,0)	73,02	(100,0)
33	576	73,25	75,25			94,00	97,63	0,00	(0,0)	1,32	(1,4)	0,00	(0,0)	96,31	(98,6)
- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	504	75,25	68,50			70,08	21,53	0,00	(0,0)	0,00	(0,0)	0,00	(0,0)	21,53	(100,0)
	570	75,25	71,50			135,72	109,22	24,22	(22,2)	0,00	(0,0)	0,00	(0,0)	85,00	(77,8)
	572	75,25	75,25			72,87	61,44	.80	(1,3)	.37	(.6)	29,08	(35,9)	38,18	(62,1)
	573	75,25	75,25			113,71	27,15	0,00	(0,0)	0,00	(0,0)	0,00	(0,0)	27,15	(100,0)
	574	75,25	75,25			92,57	84,68	39,39	(46,5)	.37	(.4)	0,00	(0,0)	44,92	(53,0)
	588	75,25	75,25		57,51	123,60	49,12	0,00	(0,0)	3,73	(7,6)	0,00	(0,0)	45,39	(92,4)
	591	75,25	75,25			139,79	13,73	0,00	(0,0)	.75	(5,4)	0,00	(0,0)	12,99	(94,6)
	593	75,25	75,25			151,83	64,58	0,00	(0,0)	0,00	(0,0)	0,00	(0,0)	64,58	(100,0)
	594	75,25	65,50			56,19	46,04	0,00	(0,0)	.37	(.8)	0,00	(0,0)	45,67	(99,2)
	595	75,25	71,50			90,97	22,80	0,00	(0,0)	.37	(1,6)	0,00	(0,0)	22,42	(98,4)
	598	75,25	75,25			58,51	32,80	0,00	(0,0)	1,49	(4,5)	2,13	(6,5)	29,18	(89,0)

[a]Percent of total influence on an individual.

the value of RISTSD was adjusted so as to make the simulated cumulative adoption curve behave properly at the beginning of the simulation; in other words, to avoid either too slow or too rapid a build-up during the first several time periods.

Influence parameters: CMAGNW, CNEHBR, CRADTV, CMLORG

A series of runs was made to explore the effect on the simulated output of changing the relative proportions of total influence resulting from print media exposure versus sociometric interaction. The values of CMAGNW and CNEHBR were varied inversely in order to adjust the percentage contribution of influence from each of the two sources for each run. The effect on the correlation between the simulated adoption times and empirical adoption times of different percentage contributions to total influence from print media exposure and sociometric influence is plotted in Figure 4.3. The highest values for the variance of empirical adoption times explained by the simulation occurred in the range between 62 to 75 percent for sociometric influence as a percent of total influence. In this range the print media contributed approximately 20 to 30 percent of the total influence. The contribution of the other two sources, electronic media and interaction with adopters at local organization meetings, was held relatively constant at between 4 and 5 percent of the total influence. These best-fit percentages hold true for one innovation in one community. They are likely to be somewhat different under other circumstances. Nevertheless the influence parameters associated with this best-fit solution should be more stable than the percentages across different situations. The question of the stability of the best-fit parameters for other innovations and in other communities

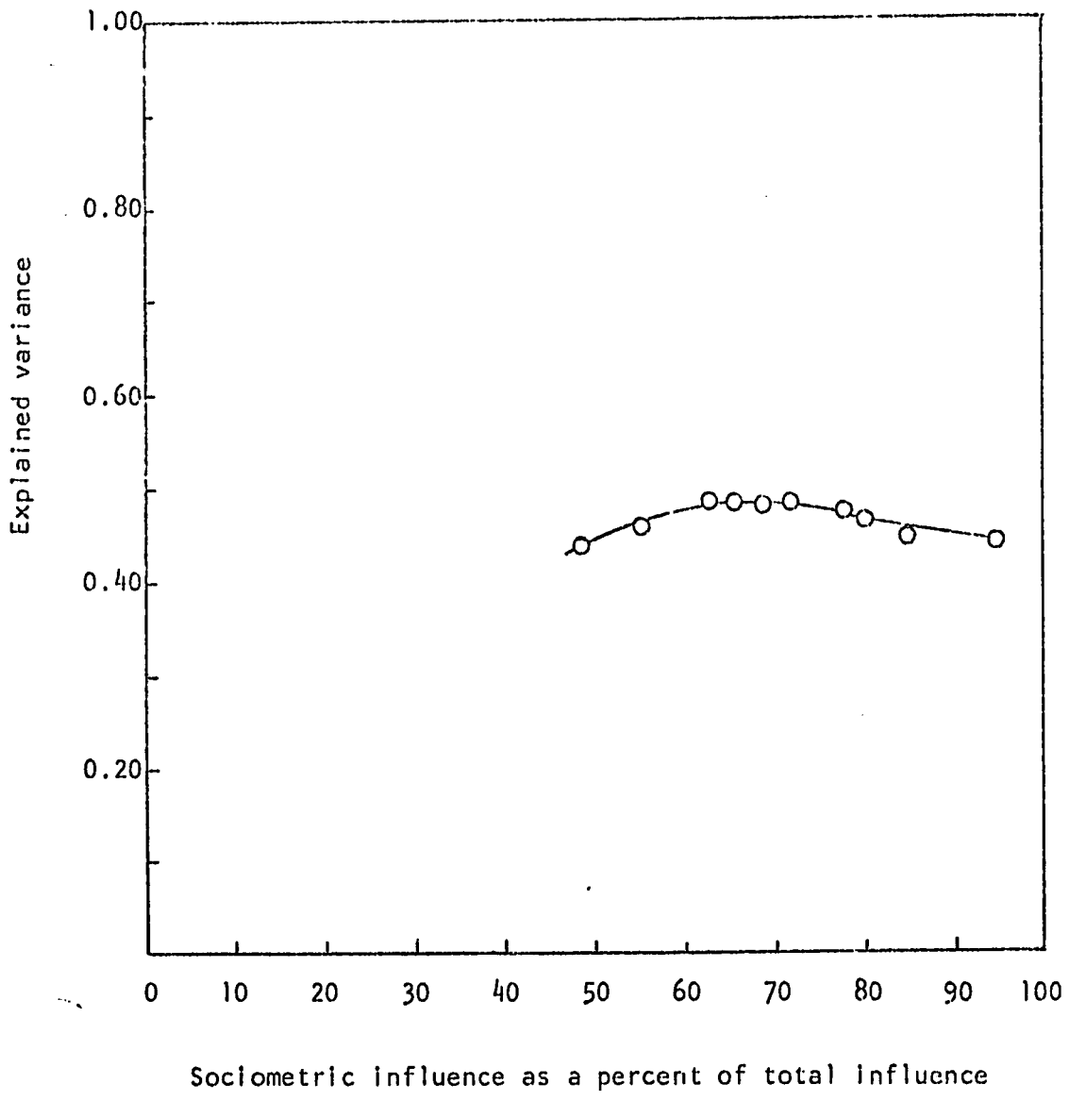

Figure 4.3 Variance explained in empirical adoption times by the simulated adoption times as a function of percent of sociometric influence. Print media varied from 1.9 to 45.5 percent of the total influence from all sources on the simulated population. The combined influence from the one agricultural radio program and from interaction with adopters at the meetings of the local cooperative varied slightly from 3.5 to 4.7 percent of the total.

will be discussed further in Chapter V.

For several reasons, no further runs were made to explore other mixes of the four influence parameters. In the first place, there are many possible mixes of the four parameters -- many more than could be conveniently explored. Further, the multiple regression analysis indicated that exposure to the one agricultural radio program and interaction with adopters at the meetings of the local cooperative had only a weak effect on year of silo adoption. Therefore these sources were restricted to have only a very minimum effect in the simulation run.

Sociometric interaction parameters:
CINFLU and CINERT

In a series of runs, CINFLU, the exponent of raw frequency-of-interaction term, was varied from 0.0 to 1.0, and CINERT, the weighting factor for the inertial effect from talking with nonadopters, was varied from 0.0 to 0.50. Results of this series of runs are shown in Table 4.10. As indicated the best-fit run occurred when CINFLU equaled 0.25 and CINERT equaled 0.25. Another series of runs in which CINFLU and CINERT were each varied slightly in the vicinity of 0.25 was made but no significant improvement in the results was noted over the results for the values above. When CINFLU was equal to 0.25, an adopter with whom discussions were held approximately 150 times during a six-month period was only about 3.5 times as influential as a person with whom discussions were held only once during a six-month period.

There may be several factors at work which would explain this result. First, it was noted in Chapter III (Table 3.19) that, in general, individuals interacted less frequently with recognized opinion leaders in the community than with their close friends and discussion partners.

At the same time, opinion leaders, particularly those opinion leaders who were also mentioned as discussion partners, were given somewhat higher credibility ratings than individuals who were named solely as discussion partners (see Table 3.20). Thus it may be that individuals who were named less frequently had somewhat higher prestige and thus proportionally greater influence per communication situation than the "run-of-the-mill" discussion partner. Second, it may be that when a potential adopter interacts very frequently with an adopter he becomes jaded to the adopter's new situation. Constant interaction with the same "new" situation makes that particular situation lose its impact and effect. On the other hand, when a potential adopter interacts with an individual whom he sees less frequently he may be more likely to inquire about any changes in that person's situation since their last meeting. This is similar to being asked by a friend whom one has not seen for a long time, "What's new?" Further, there is also a tendency to treat people as units regardless of the frequency of interaction with them. That is to say that a potential adopter may be influenced by the fact that, for example, six out of the ten persons with whom he has had conversations during the preceeding year related to his work enterprise have adopted a specific innovation, even though he may interact with three of the six adopters much less frequently than with his other contacts. All of these factors suggest that the influence resulting from interactions with adopters will be neither totally independent of the frequency of interaction nor directly proportional to it but rather proportional to some power of the raw frequency, in this case a power of 0.25.

TABLE 4.10 Effect of Varying CINFLU and CINERT on the Common Variance between Empirical Adoption Times and Simulated Adoption Times

The figures in the right-hand three columns represent the common variance between the simulated adoption times and the empirical adoption times. In the different simulation runs sociometric influence varied slightly between 69.2 and 76.1 percent of the total influence on the simulated population.

	CINERT		
CINFLU	0.00	0.25	0.50
0.00	0.436	0.457	0.446
0.25	0.477	* 0.483	0.472
0.50	0.473	0.466	0.449
0.75	0.441	0.413	0.413
1.00	0.417	0.356	0.352

* Best-fit run.

Likewise, the results indicated that it was necessary to include in the sociometric interaction equation an inertial term which took into account interaction with nonadopters. This too can be considered the result of the tendency to treat people as units and to be influenced by the percentage of one's acquaintances who have adopted the innovation. Thus, for example, a potential adopter who interacts with three adopters and no nonadopters is likely to be influenced to adopt an innovation more than the person who interacts with three adopters and four nonadopters.

Reciprocal sociometric choices

The standard simulation runs were made using the sociometric data as collected. In other words, for the sociometric interaction part of the simulation each individual could be influenced only by people whom he named as belonging to his circle of discussion partners

and opinion leaders. Most of the dyadic relationships in the simulation were nonreciprocal. Specifically, 79 percent of the 99 dyads in which the person was named solely as a discussion partner were nonreciprocal; 89 percent of the 106 dyads in which the person was named as both a discussion partner and an opinion leader were nonreciprocal; and 97 percent of the 115 dyads in which the person was named solely as an opinion leader were nonreciprocal. The high percentage of nonreciprocal dyads in the case of opinion leaders is not surprising; however, the fact that close to 80 percent of the dyads involving discussion partners were nonreciprocal is surprising. One would have expected a much lower percent of nonreciprocal dyads.

To check whether the predictive capability of SINDI 2 would be improved if the nonreciprocal dyads involving discussion partners were made reciprocal, a series of runs was made with three augmented sociometric input decks. In the first input deck all nonreciprocal dyads with a person named solely as a discussion partner were made reciprocal. The frequency of discussion was set equal to the frequency in the original dyad. A second augmented sociometric input deck was formed in the same way for all nonreciprocal dyads involving any person who was named as a discussion partner even if he was also named as an opinion leader. A third deck was made in which all nonreciprocal dyads were made reciprocal. The explained variances resulting for each run fell in the range of 0.39 to 0.40. It appears that the original sociometric deck did the best job of delineating the communication network for the flow of innovation information and influence.

Randomized sociometric data

In order to determine how much of the explained variance was accounted for by the communication network as specified in the original sociometric deck, three runs were made with three randomized sociometric decks. The randomized sociometric decks were constructed by randomly distributing the 324 persons mentioned, the variable NAMED, among the 324 dyads. The frequency of discussion remained the same for a particular dyad; only the person mentioned was changed. The explained variances for the three runs were 0.42, 0.39, and 0.41, or an average of 0.41. The correlation between the adoption times predicted from the best-fit simulation run and the empirical adoption times is significantly greater at the 0.10 level of confidence than the correlation between the adoption times predicted from the third randomized sociometric run and the empirical adoption times.[4] Thus approximately 15 percent of the total explained variance was accounted for by the communication network specified by the sociometric interaction data. Examination of the simulated cumulative adoption curves for the runs with randomized sociometric decks indicated that the original curve had been affected but not greatly. The main effect was a slight delay in the beginning of the rise followed by a more rapid rise than than the original curve. This finding adds further confirmation to the findings reported by other diffusion researchers that an individual's place in the communication network of a community can affect the time at which he becomes an adopter. Coleman, Katz, and Menzel (1966)

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[4]The correlation between the two sets of simulated adoption times was 0.910. For the method of testing the statistical difference between two correlations from the same sample, see Blalock (1960, p. 311).

reported similar findings in their study of the diffusion of a new drug among physicians.

Raw resistance factor (REGRMIX)

As was discussed earlier in this chapter, the raw resistance factor distribution (REGRMIX) was formed as a weighted average of two other distributions which were based on multiple regression analyses of the year of silo adoption. One of the base distributions, REGRM, was made up of the predicted values for the year of silo adoption which were calculated from a straightforward multiple regression equation having attitudinal and economic variables of the individual subjects as the independent variables. The other base distribution was derived in a slightly more complicated fashion. First, residuals on the year of silo adoption were predicted from a multiple-partial regression equation using the residuals of the attitudinal and economic variables as the independent variables after the communication variables had been partialled out of the analysis. This preliminary distribution of residuals was linearly transformed to a new distribution which had the same mean and standard deviation as the multiple regression distribution (REGRM). This new distribution was referred to as the transformed multiple-partial regression distribution (TREGRMP). As would have been expected, the transformed multiple-partial regression distribution (TREGRMP) had a lower correlation with the empirical adoption distribution than did the multiple regression distribution(REGRM). The raw resistance factor distribution (REGRMIX) was formed from an average of the multiple regression distribution (REGRM) weighted by f and the transformed multiple-partial regression distribution (TREGRMP)

weighted by (1 - f). The symbol f stands for a pure fractional number between zero and one. A series of five runs was made in which the weighting fraction f was set equal to the values of 0.00, 0.25, 0.50, 0.75, and 1.00. These runs changed the relative contributions of the multiple regression distribution (REGRM) and the multiple-partial regression distribution (IREGRMP) to the raw resistance distribution (REGRMIX). The results are plotted in Figure 4.4. As was to be expected, the correlation (as measured by r^2) between the regression resistance factors and the empirical adoption times increased with the increase in the relative contribution of the multiple regression distribution (REGRM) to the overall raw resistance distribution (REGRMIX). The surprising result, shown in Figure 4.4, is that the correlation between the simulated adoption times and the empirical adoption times remained relatively constant over the different compositions of the raw resistance factor (REGRMIX). One might have expected the correlation between the simulated output and the real-world data to have fallen off proportionally to the decrease in the correlation between the raw resistance distribution and the empirical adoption times for decreasing values of the weighting factor f. One might also have expected the correlation between the regression resistance factors and the simulated adoption times to have remained relatively constant for the different values of the weighting factor. In other words, the manner in which the raw resistance factors were determined should have had no effect on how SINDI 2 processed these factors in producing the simulated results. It appears that there may have been a relatively complicated interaction between the communication subprocess and the resistance subprocess as

modeled by SINDI 2. The communication variables, particularly the mass media exposure variables, can affect the simulated output in two ways. In SINDI 2 the mass media exposure variables usually affect the simulated output through the part of the model which simulates the flow of information from the mass media to the potential adopters. However, the mass media exposure variables can also affect the simulated output through their indirect contribution to predicting the regression resistance factor. One would expect that the greater the contribution of the multiple regression distribution (REGRM) to the raw resistance distribution (REGRMIX), then the larger the effect of the mass media exposure variables on the simulated output via the resistance factors in the simulation model. It appears that when the raw resistance factor (REGRMIX) is comprised primarily of the multiple-partial regression distribution (TREGRMP), then the mass media variables affect the simulated output primarily through the communication subprocess which is simulated by SINDI 2. On the other hand, when the raw resistance distribution (REGRMIX) is comprised mainly of the multiple regression resistance (REGRM), then the mass media exposure variables probably affect the simulated output through both the communication subprocess and the resistance-to-innovating subprocess but in a nonadditive manner.

Although there was relatively little change in the correlation between the simulated adoption times and the empirical adoption times for the various compositions of the raw resistance distribution (REGRMIX), rtheless it is interesting to note that the correlation reaches its maximum value at a value of f equal to approximately 0.75. As was discussed earlier in the chapter this value was considered to be a reasonable weighting factor for partitioning the common variance

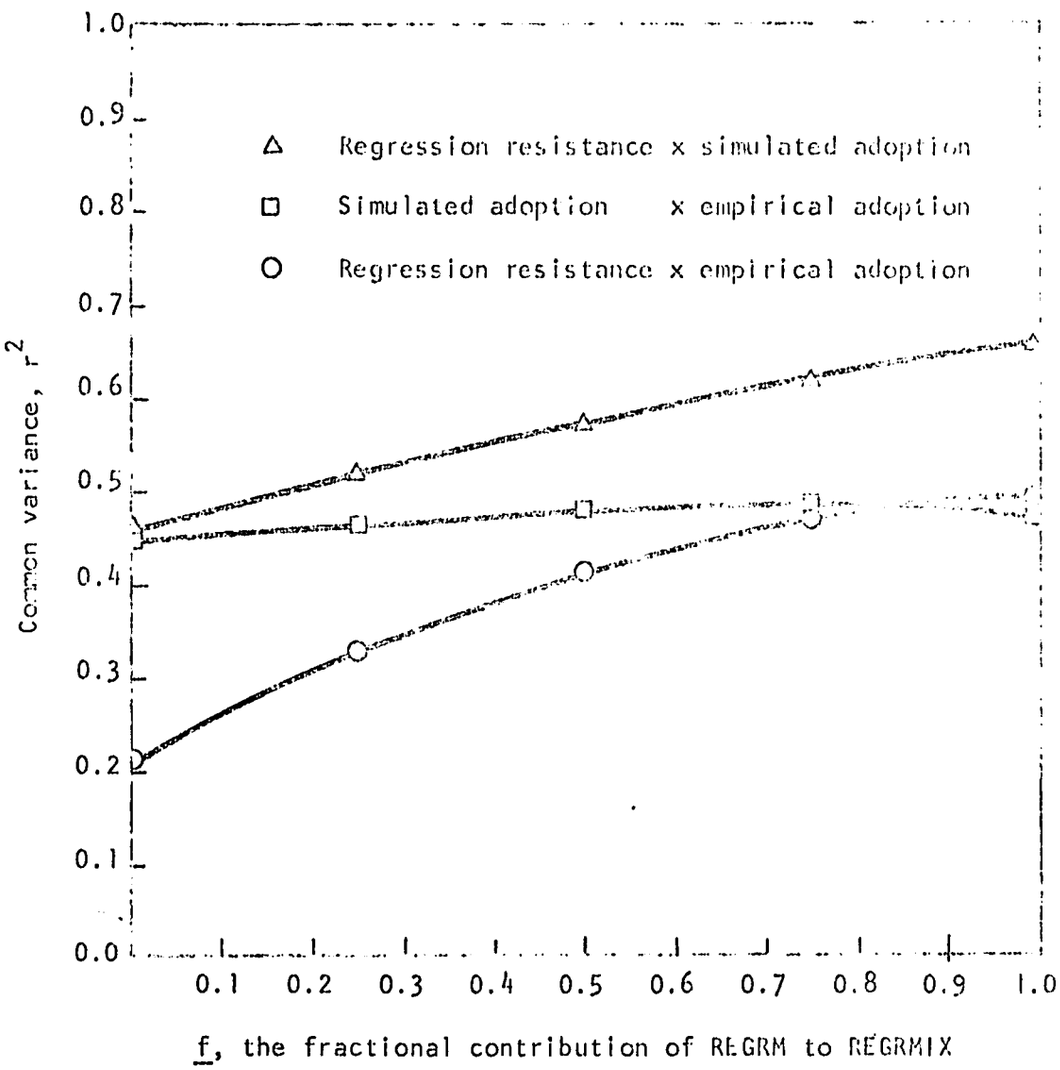

Figure 4.4 Common variances between the simulated adoption times, the empirical adoption times and the regression resistance factor as a function of the composition of the raw resistance factor (REGRMIX) in the simulation of silo diffusion. The raw resistance factor (REGRMIX) is composed of an average of the resistance factor based on a straight multiple regression analysis (REGRM) weighted by f and the transformed resistance factor based on a multiple-partial regression analysis (TREGRMP) weighted by (1 - f).

between the attitudinal-economic variables and the communication variables. This suggests, though not conclusively, that at this particular composition of the raw resistance distribution, the communication variables work through the communication subprocess and the resistance-to-innovating subprocess to make their maximum effect on the simulated output.

Credibility rating of sociometric choices

Each respondent was asked to rate each of his sociometric choices on a 0 to 10 ladder scale of credibility, which was scaled to a range of 0.0 to 1.0 for use as a multiplicative factor in the sociometric influence equations (A-33 and A-84). However, the best-fit simulation run occurred when the scaled credibility rating for all sociometric choices was set equal to the average value of 0.82.

In a simulation run in which the credibility attributes were set equal to their empirical values, the variance in the empirical adoption times explained by the simulated adoption times decreased from 0.483 to 0.456. In this run the Kolmogorov-Smirnov goodness-of-fit probability increased from 0.62 to 0.86 although the visual goodness-of-fit was not noticeably better than the visual fit seen in Figure 4.2 for the best-fit run. Since the time required to explain the scale to the respondent and to obtain the ratings for each sociometric choice was not insignificant, one concludes that it is not worth the effort to include the credibility attribute as part of the simulation model. There are probably several reasons why inclusion of the credibility attribute did not improve the predictability of SINDI 2. The first point is related to the fact that a large percentage of the sociometric dyads were nonreciprocal,

particularly those in which the respondent was asked to name people with whom he discussed matters of dairy farming. It may be that the response to this sociometric question is the natural credibility filter: respondents for the most part did not name people lower in credibility and status than themselves but rather named people from whom they felt they had received useful information over the years. It may be that, as suggested earlier, information and influence regarding technical innovations flow through sociometric communication channels which in fact are very nonreciprocal. This notion fits in with the fact that 38 percent of the persons who were named received a credibility rating of 10, with 79 percent of the persons who were named receiving a rating of 7 or greater. One also suspects that the test-retest reliability of the credibility measure would be low. And finally, setting the exponent (CINFLU) of the interaction frequency in the sociometric influence equation (A-33) to a value of 0.25 may increase the relative influence of opinion leaders (with whom discussions were held less frequently) versus discussion partners more than the minor variations in the credibility ratings increase their influence.

Community entry time and dairy operation start-up time

A check was made to see the effect on the simulated output of ignoring the fact that 20 simulated individuals migrated into the community after the starting time of the simulation and 22 individuals began their dairy operations after the starting time. When a run was made in which each individual's community entry time and the operation start-up time were arbitrarily set to occur prior to the simulation starting time, the explained variance fell to a value of 0.425 for N of 82. The

common variance between the regression resistance and the empirical adoption times also fell to a value of 0.435 from 0.464. One concludes then that inclusion of the community entry times and enterprise start-up times has an effect on the simulated output (though not quite statistically significant).

Number 564's adoption time

Respondent Number 564 presented an interesting problem. He received the highest number of sociometric nominations, a total of 54. Because the domain of his influence was so large, the time at which he became an adopter would greatly affect the course of the diffusion process. Although he had been nominated by 54 other persons, he himself named only one other individual, Number 562, as an opinion leader-discussion partner. Number 562 entered the community in 1963 as an external adopter, which meant that he would not start influencing Number 564 until that time. Because Number 564 was so influential in the community it was decided that for the standard simulation runs he would be preset to adopt at his empirical adoption time of 1962.5.

In a run in which Number 564 was allowed to be a fully simulated individual, he adopted at 1961.75 with close to 100 percent of the influence upon him coming from the print media. The explained variance for this run rose from 0.483 to 0.490.

A run was also made in which Number 564 was preset as an innovator. The purpose of this run was to allow Number 564 not only to act on his own behalf during the simulation run but also to simulate the influencing activity of Number 652. As was mentioned earlier, Number 652 was an important opinion leader with regard to silos during the 1950's and early 1960's but

had retired from dairy farming several years before data collection in 1967. Since Number 652 had not been interviewed it was not possible to include him in the simulated population. The explained variance for this run increased to 0.494.

This latter run might have been considered as the best-fit run except that at the aggregate level the fit between the simulated and empirical cumulative adoption curves declined noticeably. Further trial-and-error variation of the tuning parameters in order to improve the fit at the aggregate level would be needed and this might change the micro level correlation. The important point is that there was some improvement in the micro level correlation when Number 564 was preset as an innovator in order to simulate the influence of Number 652 during the late 1950's

"What-if" run: doubling mass media messages

Once the model has been tuned to the real-world diffusion process and can be assumed to be a reasonably valid representation of this process, then it is possible to ask a question of the variety "What would happen to the diffusion curve if certain changes were made in the controllable inputs?" "Controllable" implies controlled from the standpoint of an external change agent. Figure 4.5 shows the effect on the cumulative adoption curve when the quantity of information carried by the mass media is doubled during the eighteen years of the simulation run. The behavior of the model suggests that the rate of innovation diffusion would increase somewhat but certainly not proportionally to the increase in the flow of mass media messages.

Simulation of Forage Grass Plot Diffusion

In a final series of runs SINDI 2 was applied to the diffusion of

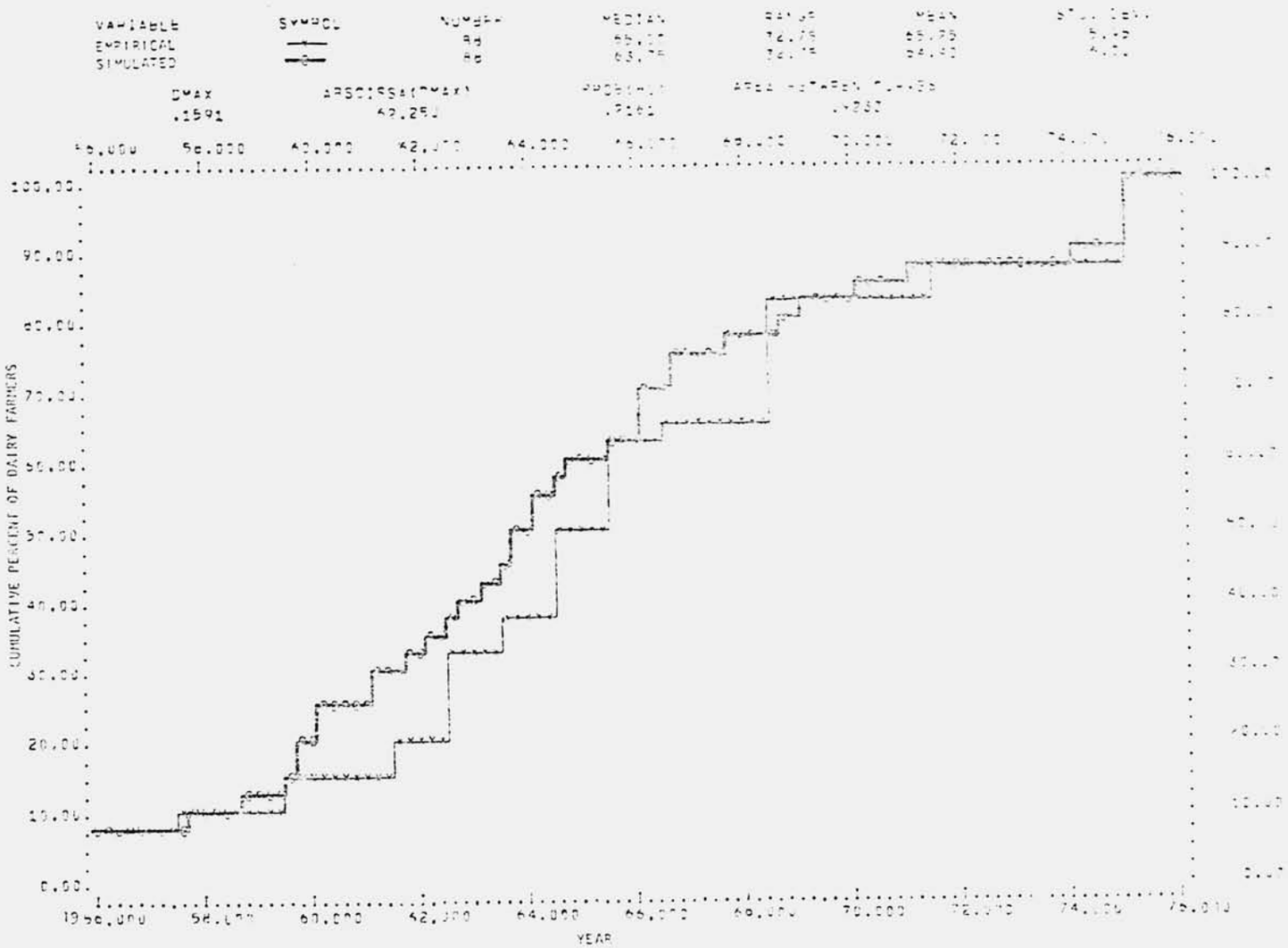

Figure 4.5 Effect on the simulated cumulative adoption curve of doubling the quantity of silo information carried by the mass media.

forage grass plots in Conceição do Rio Verde. As was discussed earlier, silo diffusion had been chosen as the process to be simulated in the first series of runs because the data on year of silo adoption appeared to be reliable and predictable. Once the eight tuning parameters were obtained from the best-fit simulation run for silo diffusion, they were used in a simulation run to predict the diffusion of forage grass plots. The use of the same tuning parameters was deemed valid because as can be seen in Figure 4.6 the rates of diffusion for the two diffusion processes were approximately equal. The only difference between the two processes appeared to be that silo diffusion lags forage grass plot diffusion by [illegible] years.[5]

A multiple regression analysis was performed in order to determine each simulated subject's resistance to adopting a forage grass plot. Table 4.11 summarizes the contribution of three attitudinal economic variables to the multiple correlation coefficient ($R = 0.[illegible]$; $R^2 = 0.28$). A multiple-partial correlation analysis on year of adoption of forage grass plot was not performed for two reasons. In the simulation of silo diffusion, the percent variance in the empirical adoption times explained by the simulated output was relatively insensitive to variations in REGFMIX as

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[5] If the empirical cumulative adoption curves approximate the logistic growth curve, the data points should fall in a straight line when they are plotted on semi-logarithmic coordinates in the form P/(K-P) versus time. This is the case because the logistic growth equation can be transformed to the linear form:

$$\log_e \left(\frac{P}{K - P}\right) = a + bt$$

where P = cumulative percent of adopters
K = equilibrium percent of adopters (in this case, taken to be 100 percent)
t = time (in this case, calendar years)
a = intercept (a constant)
b = slope (a constant).

In Figure 4.6 the empirical cumulative adoption curve for silo diffusion approximates the logistic quite well; the curve for forage grass plot diffusion does so after about 20 percent adoption.

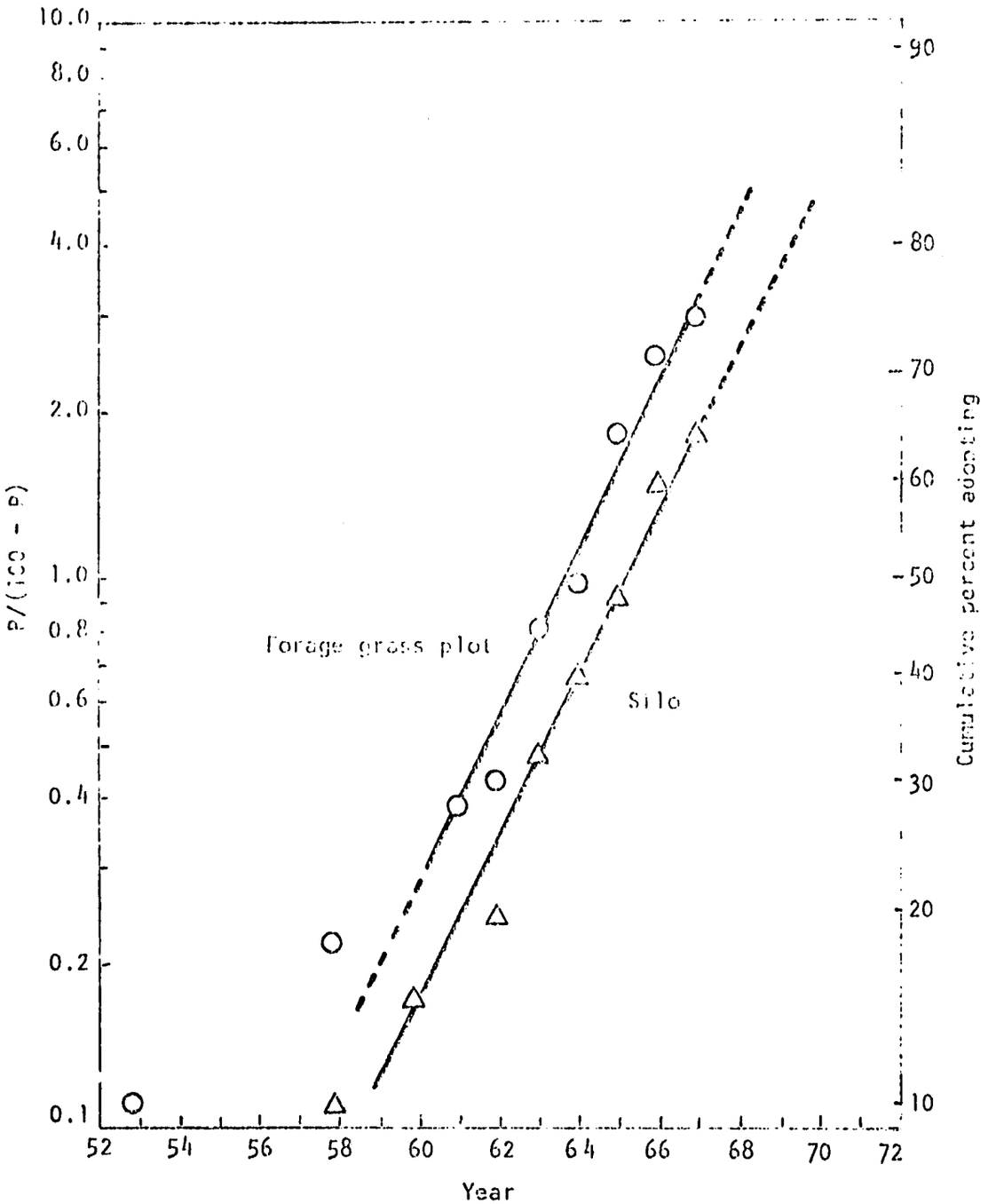

Figure 4.6 Linear form of logistic growth curves showing the diffusion of forage grass plots and silos among dairy farmers (N = 97) in Conceição do Rio Verde.

determined by different mixes of TREGRMP, which was based on the multiple-partial regression analysis, and REGRM, which was based on the straight multiple regression analysis. Further, the four communication variables which were partialled out in the multiple-partial correlation analysis of silo adoption only accounted for 11 percent of the variance in year of adoption of forage grass plot.

TABLE 4.11 Multiple Correlation Analysis of Year of Adoption of Forage Grass Plot

The overall multiple correlation coefficient R is equal to 0.53 and R^2 is equal to 0.28. The negative correlations imply that the greater the degree to which a subject possesses the attributes the earlier he will adopt the innovation or equivalently, the lower is his resistance to adopting the innovation.

Attitudinal-economic variables	Beta weight	Partial correlation coefficient	Significance
Positive orientation toward risk[a]	-0.26	-0.29	0.011
Farm cultivation power ($\log_{10}$)[b]	-0.27	-0.26	0.034
Stable improvements[c]	-0.21	-0.21	0.071

[a]Based on the item: "If a person already has the means for living comfortably, do you think he should (a) be satisfied or (b) risk part of what he has in order to improve the future?"

[b]An index found by weighting the use of manpower, horsepower, ox power, and tractor power.

[c]See Table 3.3.

The mass media message inputs dealing with forage grass plots were determined in the same manner as for the case of silos. Table 4.12 summarizes the content analysis of four magazines to determine the quantity of information carried about forage grass plots. Overall, these four magazines carried about 12 percent less information about

forage grass plots than information about silos. The information inputs from the other magazines were estimated to reflect the message inputs from these four magazines in the manner discussed earlier in the case of silo information. The newspapers were assumed to carry the same amount of information about forage grass plots as about silos.

TABLE 4.12 Quantity of Information about the Use of Forage Grass Plots Appearing in Four Agricultural Magazines

The data in the right-hand column below are based on content analysis of selected issues in the period from 1963 to 1967.

Magazine	Number of issues analyzed	Average quantity of information per six-month period (square inches)
Revista dos Criadores	21	27
Coopercotia	17	5
O Dirigente Rural	26	215
A Realidade Rural	28	310

The results of a simulation started at 1955.0 with 10 percent of the 88 subjects preset as innovators and with Number 564 preset to adopt at 1957.5 are shown in Figure 4.7. The simulated curve follow[illegible] empirical curve better than in the case of silo diffusion; the [illegible]rected Kolmogorov-Smirnov probability is 0.86. However, good agreeme[illegible] the aggregate level is expected, since the two diffusion proce[illegible] appear to be so similar, and also the discontinuity in the emp[illegible] adoption curve at 1968.5 is less than in the case of silo diff[illegible] The percent contribution from each of the four channels to the influence on the simulated population is as follows:

Channel	Percent of [illegible]
Mass media [illegible]	21.[illegible]
Radio programs	1.9
Local meeting [illegible]	[illegible]
Sociometric interaction	75.7

At the micro level, Table 4.15 presents a comparison between the performance of SINDI 2 in predicting individual cases of forage grass plot adoption and the performance of the general linear regression model of innovation diffusion (LRMID) which predicted individual adoption times from seven independent attitudinal, [illegible], and [illegible] variables. SINDI 2 explained approximately 26 percent of the variance in

TABLE 4.15 Comparison of Empirical Performance of SINDI 2 and the General Linear Regression Model of Innovation Diffusion (LRMID) [illegible] Individual Adoption Times in the Case of Forage Grass Plot Diffusion

Correlations are based on an N of 69 which excludes innovators and external adopters. "Adoption" refers to the time at which an individual subject adopted the forage grass plot.

Variables	Correlation coefficient r	Coefficient of explained variance r^2
Simulated adoption x empirical adoption . . .	0.507	0.257
Regression resistance x empirical adoption . . .	0.458	0.210
Regression resistance x simulated adoption. . . .	0.786	0.618
Linear regression model of innovation diffusion (LRMID)		
Predicted adoption x real-world adoption . . .	0.460	0.212

empirical adoption times and thus performed somewhat better than the linear regression model which explained approximately 21 percent of the variance. However, SINDI 2 explained only about half as much of the variance in empirical adoption times in the case of forage grass plot diffusion than

it explained in the case of silo diffusion. The controlling factor in this case was that the regression resistance explained only 21 percent of the variance in the empirical adoption times while accounting for approximately 62 percent of the variance in the simulated output. The ability of SINDI 2 to predict the empirical adoption times was constrained from the very beginning by the low correlation between the resistance factors and the empirical adoption times.

A series of runs was made using the three randomized sociometric decks which were used for sensitivity testing of SINDI 2 in the case of silo diffusion. The variances in empirical adoption times explained by the three runs were 0.25, 0.20, and 0.23 for an average of 0.22. The variance explained by the standard simulation run (0.20) was higher, but not significantly, than the variance explained by the third randomized sociometric run.

In the application of SINDI 2 to predicting the diffusion of forage grass plots, one concludes that although SINDI 2 performed well in producing a simulated cumulative adoption curve at the aggregate level, it did not predict the individual adoption times very well at the micro level. The author feels that the low predictability at the micro level resulted from the low reliability of the empirical data on adoption times for forage grass plots.

CHAPTER V

VALIDITY OF SINDI 2

Now we shall discuss the general validity of SINDI 2, first considering whether SINDI 2 is a valid model of the particular diffusion system discussed in Chapter III, and second, considering to what extent SINDI 2 may be generalized to other situations.

Validity of SINDI 2

Hermann (1967) has suggested five criteria for judging the validity of a simulation model: (1) face validity, (2) internal validity, (3) event validity, (4) variable-parameter validity, and (5) hypothesis validity. The validity of SINDI 2 as applied to the diffusion of silos and forage grass plots in a rural Brazilian township will be discussed in terms of these five criteria.

Face validity

Face validity is the prima facie plausibility of the overall structure of a simulation model. Are the important entities, variables, and sub-processes of the real-world process adequately taken into account by the model? The survey of dairy farmers in Conceição do Rio Verde revealed that the most important sources of information and influence were other dairy farmers and the mass media. SINDI 2 modeled the flow of information and influence through both these channels. Thus on this count the design of SINDI 2 appears to be plausible. However, the field survey also indicated that other sources played a role in the

diffusion process. These sources included dairy farmers living outside the community, folders and brochures, agricultural fairs, technical experts, stores and cooperatives, commercial agents, extension agents, special meetings, and agricultural schools. The influence from these sources was not simulated because their role in the diffusion process was difficult to model adequately or they played a relatively unimportant role in the overall diffusion process. Discussion of some of these specific sources follows.

As was mentioned earlier, approximately 20 percent of the sociometric choices made by the 88 simulated individuals were with individuals outside the simulated population. There was no easy way to simulate directly the influence on the simulated population from individuals outside the population. The assumption was made that the individuals not included in the simulated population would not be too much different from the individuals who were included in the simulated population. Thus the empirical constant which determined the extent of influence resulting from interaction with adopters was made large enough to take into account that some of the potential adopters among the simulated populati be interacting with adopters outside the simulated population.

The role of agricultural schools in the diffusion process was not modeled by SINDI 2. The questionnaire did not make it clear whether reference to agricultural school as an influential source meant that the respondents were influenced while they attended school as students or while they attended special workshops or other activities as adults. In the case of silo diffusion four subjects (508, 510, 511, 534) indicated that the agricultural school at Lavras (about 75 miles away)

was the first and most influential source. However, only Subject 511 reported attending an agricultural school as a student. During the simulation runs Subject 508 was preset as an innovator. In the case of forage grass plot diffusion three subjects (506, 508, and 534) said the agricultural school at Lavras was the first and most influential source and one subject (513) mentioned the agricultural school at Viçosa as a first and most influential source. (Viçosa is about 200 miles distant.) Two of these subjects (506 and 513) reported attending an agricultural school as students. During the simulation runs Subject 513 was preset as an innovator, and Subject 506 was preset as an external adopter. Therefore a certain amount of distortion was introduced into the simulation runs by only allowing the simulated individuals who had indicated that an agricultural school was the main source of influence to be affected in the simulation runs by the mass media and interpersonal communication.

Folders and brochures were mentioned as frequently as magazines and newspapers as sources of information about both silos and forage grass plots. Although the author had collected samples of brochures and folders printed by various organizations about silos and forage grass plots, it was not possible to obtain much data on where and under what circumstances each of the particular folders might have been available to the farmers in Conceição. For this reason no attempt was made to simulate the effect of these media on the diffusion process by incorporating them as a source of influence in SINDI 2. None of the farmers in Conceição cited folders as a most influential source, so excluding them from the model probably did not introduce too much distortion.

Several farmers mentioned that they had been informed and/or influenced by a technical expert to adopt a silo or forage grass plot. These technical experts were associated with the Campinas Institute (an agricultural research institute near São Paulo), the Bank of Brazil, the Nestlé Corporation in Três Corações, and the Rural University of Minas Gerais. It would have been impractical to simulate the influence from these few but varied sources.

Most of the remaining sources (agricultural fairs, stores and cooperatives, commercial agents, extension agents in neighboring communities, and special meetings) were mentioned less frequently as general sources of information and much less frequently as the most influential source than the sources which were included in the model.

In considering face validity, it is also necessary to discuss the way in which the decision-making processes of each individual potential adopter were modeled in SINDI 2. SINDI 2 did not actually model each individual's information processing and decision-making. To have done this would have carried the model to a level of detail that was not warranted by the resources available to conduct this type of field research nor by the accuracy and reliability of the other types of data utilized in the simulation. Instead, it was assumed that when the cumulative sum of influence from the various sources exceeded an individual's resistance factor, he became an adopter. The resistance factor for each individual was predicted using a multiple regression equation with attitudinal and economic variables as predictor variables. This method provided a crude but simple mechanism for simulating how individuals with different resistances to innovating respond to the innovation messages which impinge on them from their enviornment. The

method ignores such phenomena as forgetting past persuasive communications as well as the purposeful delay in the actual adoption of a particular innovation because of lack of materials, credit, or other more pressing tasks at hand.[1] This method is not a very sophisticated method for handling the important decision-making subprocess as part of the overall diffusion process, but one which the author thought consistent with the level of detail present in the rest of the model.

SINDI 2 also does not take into account the possibility of negative communication about an innovation circulating through the social system. This did not matter so much in the particular real-world situation to which SINDI 2 was applied. In this case it was assumed by the author that once the innovation had diffused to about 10 percent of the population, there would be very little negative communication. The presence of negative communication probably would have been manifested in a relatively high disadoption rate. In this situation, however, none of the adopters of the silo in Conceição had reported disadopting the innovation and only one farmer had discontinued the use of his forage grass plot. Although SINDI 2 did not specifically model negative communication about the innovations it did take into account an inertial effect on a potential adopter resulting from the presence of nonadopters among his circle of discussion partners. To take into account this inertial effect, a certain amount of influence resulting from interaction with nonadopters was subtracted from the influence from adopters among an individual's circle of discussion partners. However, an individual's

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[1]Amstutz (1967, pp. 153-245) has included in his models of consumer behavior provisions for forgetting, selective perception, selective retention, selective exposure.

influence score was never allowed to drop below zero with respect to the innovation. Therefore it was not possible in SINDI 2 for an individual to hold a negative attitude toward the innovation.

In formulating SINDI 2 it was also assumed that many of the parameters and entity attributes were independent of time. For example, all mass media exposure probabilities were considered to remain constant during the course of the simulation run and were assigned values current at the time of the data collection in 1967. Nevertheless it is highly likely that these probabilities change over the course of a simulation run. The sociometric communication network was also assumed to remain constant over the course of the simulation with one exception: individuals who migrated into the community were not considered part of the network until they had entered the community. Again, it is likely that the patterns of friendship and communication change over time. As was mentioned earlier, one dairy farmer who was named by twelve farmers as a first source of information about silos and by six farmers as a most influential source had retired several years before the data collection and therefore was not included in the simulated population. It is difficult to estimate how much distortion was introduced by the assumption of unchanging mass media exposure probabilities and an unchanging communication network over the eighteen years of simulated time.

Thus SINDI 2 meets the test of face validity to the extent that it simulates the important subprocesses which contribute to the overall diffusion process. It is the author's contention that for the particular community and the particular innovations to which the model was applied, SINDI 2 is a plausible representation of the diffusion process.

Internal validity

Internal validity is the extent to which the internal operations of the model are logically consistent. Hermann suggests that the internal validity of a stochastic model is high when the variance of the output variables between runs in which the inputs are held constant is small. However, in the case of a deterministic, expected-value model like SINDI 2, there will be no variance between runs with the same inputs. One check of the internal logical structure of a deterministic model is a close inspection of the logic of the computer program itself. During the program debugging and testing of SINDI 2, several logic errors in the computer program were detected and corrected. That being the case SINDI 2 as a computer program is deemed to be logically consistent. Another check on the internal validity of SINDI 2 is the inspection of the percentage contributions of the various subprocesses of the model to the simulated output. SINDI 2 takes into account two basic processes. The first is the flow of information and influence through the mass media and interpersonal communication channels. The second important subprocess is innovation decision-making by each potential adopter. In the cases of both silo diffusion and forage grass plot diffusion, the resistance-to-innovating factor which was predicted from a multiple regression of attitudinal-economic variables accounted for 60 percent of the variance in the simulated adoption times. Consequently, the communication processes which were simulated in SINDI 2 must have accounted for the remainder of the variance in the simulated adoption times -- approximately 40 percent. The communication processes would take into account differences among the simulated individuals in their exposure to the mass media messages, as well as differences in their

interaction with earlier adopters. A 40/60 ratio between external influence processes and the situational factors of the individual decision maker seems reasonable for the contribution of these two processes to the overall diffusion process. One would expect that situational factors should weigh more heavily in the overall diffusion process than the external stimuli.

Event validity

Comparing the simulated outcome with "natural" events is the basis for determining the event validity of a simulation model. Checking for event validity can also include comparing between aggregate patterns of behavior. It is in connection with this type of validity that one most encounters the notion of goodness-of-fit between the simulated output and the real-world phenomenon.

At the macro or aggregate level SINDI 2 produced a simulated cumulative adoption curve that was as good a fit as could be obtained given the discontinuities in the empirical cumulative adoption curve which resulted from the arbitrary assignment of future adoption times to nonadopters at the time of data collection. A reasonably good fit was also obtained in the case of forage grass plot diffusion. However, a good fit at the macro level does not necessarily mean that the model has proven to be a valid model. A fit equally as good probably could have been obtained simply by sampling from a normal probability distribution with the same mean and standard deviation as the empirical distribution that was being simulated. Also the number of free parameters which can be specified by the researcher for SINDI 2 facilitates obtaining a reasonably good fit with the macro empirical data. Nevertheless at the macro level the results from applying SINDI 2 to a particular diffusion

system were an improvement over the results obtained when SIMDI 1 was applied to a particular diffusion situation. This difference is to be expected because SIMDI 2 models the diffusion process in more detail than did SIMDI 1.

At the micro level one may check the event validity of SIMDI 2 by comparing the simulated adoption times with the real-world adoption times. On this criterion SIMDI 2 explained 40 percent of the variance in the empirical adoption times for silo, slightly less than was explained by the general linear regression model. In the case of forage grass plot diffusion SIMDI 2 explained about 25 percent of the variance in simulated adoption times, slightly more than was explained by the general linear regression model. For several reasons one would have expected SIMDI 2 to have performed better at the micro level than the general linear regression model. First, a simulation model is a dynamic model of a dynamic process, whereas the linear regression model is a static model of a dynamic process. Some researchers would even hesitate calling a multiple regression equation a "model." Second, a simulation model can take into account differences in the level of external stimuli impinging on the diffusion system over time. A linear regression model cannot easily accomplish this. Third, a simulation model can model the sociometric interactions which most researchers agree play an important role in any diffusion process.

Variable parameter validity

Sensitivity testing is a method which facilitates checking how the variation in the input value of a particular variable or parameter affects the simulated output while the other input data are held constant. The

values of certain of the parameters may have to have been determined by the empirical trial and error comparison of the simulated results with the real-world results until satisfactory agreement is obtained. Since the values of these parameters have been empirically determined, the sensitivity of the overall model to changes in these values must be assessed in order to determine how important accurate values for these parameters are to the functioning of the overall model. The way in which the model behaves in response to changes in the input parameters and variables can also be used to make inferences about the overall validity of the model.

For example, the reason that SINDI 2 should be an improvement over the linear regression model for predicting patterns of innovation diffusion is that the simulation model explicitly takes into account the interpersonal communication which takes place within the communication network of the community. When a series of runs was made in which randomized sociometric input decks were used in place of the regular input data on the sociometric interaction patterns, the percent of variance explained in the empirical adoption times by the simulation model decreased by 15 percent. This particular sensitivity check on the effect of the sociometric input data provides a partial validation that the model does adequately represent one of the important sub-processes in the overall diffusion process.

The sensitivity checks on the percentage contribution of the sociometric influence as compared with the influence from the print media also help to establish the variable-parameter validity. It was found that the maximum explained variance occurred at a set of values for the influence parameters (CMAGNV, CRADTV, CMLORG, and CNEHBR) which

resulted in the sociometric influence accounting for approximately 70 percent of the total influence from all sources on the simulated population. The influence from the print media accounted for about 25 percent while the influence from the one radio program and the interaction with adopters at the meetings of the cooperative accounted for about 5 percent. Although no sensitivity runs were made in which the percentage contribution from the radio program and the cooperative meetings were varied, on the basis of the experience with the multiple correlation analysis one would not have expected any improvement in the overall explained variance by the simulation model. Thus the percentage distribution of the contribution of each one of the simulated sources to the total influence on the simulated population seems reasonably plausible. One would have questioned the validity of the model, for example, if the sociometric interaction had accounted for only 5 percent of the total influence.

In the case of the sensitivity checking runs with the sociometric interaction parameters (CINFLU and CINERT), it was found that the influence which resulted from interaction of potential adopters with actual adopters was not a direct function of the raw frequency of interaction but rather a function of the raw frequency raised to a power of 0.25. The effect of this exponential term in the sociometric influence equation was to give the less frequent interactions greater weight relative to the more frequent interactions. In a similar manner, it was found that it was important to include an inertial effect from a potential adopter's interaction with other discussion partners who had not yet adopted the innovation.

As a result of the sensitivity checking runs summarized in the

paragraphs above, one concludes that the values of the "best-fit" parameters seemed reasonable within their own context and at the same time caused SINDI 2 to behave as a plausible model of the overall diffusion process.

Hypothesis validity

Hypothesis validity refers to the extent that hypothesized relationships between two or more variables in the observable universe are also present in the simulation model. Hypothesized relationships can either be programmed directly into the model or they can manifest themselves as a by-product of the complex interactions represented by the various processes simulated by the model.

The first case is an answer to the question "Have the important relationships which characterize the real-world process been explicitly programmed into the model by the designer of the model?" For example, past diffusion research has shown that the attitudinal and economic characteristics of the potential adopters have an effect on when potential adopters adopt an innovation. This relationship between noncommunication variables and time of innovation adoption is explicitly introduced into the SINDI 2 model by associating with each simulated individual a resistance-to-adopting-innovation-X which is predicted by means of multiple regression from the attitudinal-economic variables.

However, it is not always possible nor desirable to program explicitly into the model all the relationships between variables of the process which are observed in the real world because, at worst, the model may become over-determined and not function properly, or at best, it may lack parsimony which is a desirable goal in the

development of any scientific model.

Thus, a more stringent test of a model in terms of hypothesis validity is the extent to which the model manifests relationships of the real world which have not been explicitly programmed into it. When SINDI 2 was applied to a real-world diffusion system, the simulated output manifested several such relationships. For example, diffusion researchers have observed that (a) "impersonal sources of information are more important than personal sources for relatively earlier adopters of innovations than for later adopters" and (b) "cosmopolite sources of information are more important than localite sources for relatively earlier adopters of innovations than for later adopters" (Rogers, 1962, p. 179). Examination of the detailed listing of the simulated adoption times and the percentages of influence resulting from exposure to the print media, as shown in Table 4.9, reveals that the earlier adopters have a higher percentage of influence from the print media than do the later adopters. It is true that some proportion of this relationship is the result of the intercorrelation between the attitudinal-economic variables and the mass media exposure variables. Because the regression resistance results from a mixture of the multiple-partial regression distribution and the multiple regression distribution, not all of the effect from the mass media exposure variables is controlled out in the prediction of the raw resistance distribution. Nevertheless, it is true that the relationship between the print media exposure variables and the time of adoption is not explicitly introduced into the model even though it shows up in the simulated output.

Diffusion researchers have also found that the cumulative adoption curve which results from the plot of the cumulative number of adopters

who have adopted as a function of time usually takes the form of an S-curve, also referred to as the logistic growth curve. Under event validity we have already discussed the degree of agreement between the simulated output and the empirical output at the macro level. However, under hypothesis validity we can specifically discuss the shape of the curve. As can be seen from the plots of the simulated curves in Figures 4.2 and 4.7, the simulated curves do take on the shape of an S-curve. This was not the case for the simulated output from SINDI 1 (see Figure 1.1). Again, it was not explicitly programmed into SINDI 2 that the resulting simulated output should be an S-curve. The fact that the simulated curve turned out to be an S-curve is further evidence of hypothesis validity.

General Applicability of SINDI 2

In thinking about the validity of SINDI 2, it is also useful to consider how well the model could be applied in other instances. In its present mode of operation SINDI 2 is programmed to facilitate the trial-and-error adjustment of the various tuning parameters in order to achieve the best-fit solution of the simulated results with the real-world results. This mode of operation could be applied to any innovation in any community for which the basic diffusion process is essentially the same as the one being simulated by SINDI 2. Note, however, that SINDI 2 could not be applied to diffusion in a community in which an extension agent played an important role in the diffusion process.

In considering general applicability of the model, one usually has a different question in mind: given the model has been tuned to the diffusion of one innovation through one community, how well can the model

predict the diffusion of the same innovation in another community, or the diffusion of a different innovation in the same community, or the diffusion of a different innovation in a different community? In other words, what values of the various tuning parameters and other input data can be applied directly to the new situation and what values must be recalculated?

Perhaps the simplest case to consider is the application of SINDI 2 to the same innovation diffusing in another community. The innovation may diffuse at a faster rate, at the same rate, or at a slower rate in the new community than in the original community. A number of factors can influence the rate of the diffusion process at the community level. Griliches (1957) reviewed several factors related to the profitability of the innovation which can affect the diffusion rates within communities across widely differing regions.

For 76 communities in Minas Gerais with extension agents, Phase I of the Brazil Diffusion Project investigated community-level variables and extension agent strategies which were associated with differences in levels of innovation adoption (Whiting et al., 1968). However, for purposes of this discussion let us consider the simpler case of an innovation diffusing in communities within the same ecological region and also consider only those variables which are taken into account by SINDI 2. Under these restrictions, one would not expect any differences between communities in the quantity of messages carried by the mass media, since it could be assumed that the same mass media channels are generally available throughout the region. However, if there should be differences in the mass media inputs, SINDI 2 is designed to take them into account. More importantly in terms of these factors modeled by

SINDI 2, one might expect that differences in the integration of the communication network within the community might affect the rates of diffusion. These differences would be handled by the specific inputs which summarize the sociometric data. Other differences such as those in the general level of exposure to the mass media would also be handled by SINDI 2 in terms of the input data. There also may be differences in the average level of attitudinal, demographic, and economic variables which in the original community have shown a relationship to individual resistances to adopting innovation X. In order to take these latter factors into account there would have to be a slight alteration in the procedure for handling the simulation resistance factor. Currently, SINDI 2 linearly transforms the raw resistance factor which has been predicted externally by multiple-partial regression to the simulation resistance factor which is measured on a ratio scale. Once this factor has been properly scaled in the original community, it would be possible to transform the coefficients in the regression equation(s) so that the equation(s) would directly predict the transformed simulation resistance factors for any community. The greater was the similarity of the new community to the original community, the greater would be one's confidence about using the regression equation(s) to predict the simulation resistance factors for the new community. One would expect that the influence parameters (CMAGNW, etc.) and the sociometric interaction parameters (CINFLU and CINERT) would remain the same. In summary then, we would conclude that for the case of simulating the same innovation in a different setting, one would only have to alter the input data associated with each individual in the new community.

Next we consider the case of simulating the diffusion of a different innovation in the same community. The mass media exposure probabilities and the probabilities of attending local organizations would remain the same for the simulated population. Likewise, the interpersonal communication network as defined by the sociometric data would remain unchanged. On the other hand, the amount of information entering the community via the mass media channels would have to be altered for a different innovation. One would also certainly expect that the average resistance parameters (RISTMN and RISTSD) would be different for different innovations.

The case of the diffusion of forage grass plots described in the previous chapter represented a special case because it was determined ex post facto that the diffusion of forage grass plots proceeded at the same rate as the diffusion of silos except for a constant time lag of 1.6 years. In this special case, the same resistance parameters were used in both diffusion processes. In most cases, different innovations are likely to diffuse at different rates within the same community and thus the average resistance parameters will be different.

Even though the simulation of forage grass plot diffusion was considered a special case, nevertheless, it was found that it was necessary to determine a new regression equation for predicting the raw resistance factor for individuals. This implies that there is an interaction between the characteristics of an innovation and the characteristics of the individuals who are deciding whether or not to adopt the innovation. For example, as the respondent mentioned during the interview presented in Appendix B, whether or not a person adopts the use of tick pesticide depends on whether he has adopted the use of the Dutch breed of dairy

cattle. Thus, one would not expect that a general regression equation would work equally well for all innovations.

Although it is probably safe to assume that the sociometric interaction parameters (CINFLU and CINERT) and perhaps the mass media influence parameters (CMAGNW and CRADTV) would be the same for all innovations, this probably cannot be assumed for the sociometric influence parameters (CMLORG and CNEHBR) because it cannot be assumed that the basic communication and influence processes work the same for all innovations. Given a certain frequency of conversation between two individuals, one cannot assume that both innovations would be discussed with the same frequency or that the persuasive influence of indirect, nonverbal communication would be equivalent in all situations. For example, the persuasive influence per unit interaction is probably greater in the case of a silo than it is in the case of keeping milk production records because milk production records do not have the visual impact from a distance that a silo has. Also a farmer might consider his silo to be a prestige symbol which he is more likely to talk about than keeping milk production records which would be an aspect of his personal business operation.

In summary, the discussion above suggests that to predict the diffusion of a different innovation in the same community probably requires in most cases the recalculation of the multiple regression equation to predict the resistance factors and then the application of SINDI 2 in the trial-and-error mode in order to determine the appropriate values for at least some of the tuning parameters.

Ideally further research into the determination of parameter values for social psychological simulation models might lead to the

development of a general regression equation for predicting simulation resistance factors for a specific type of enterprise such as dairy farming in a specific region. The coefficients of the equation might be expressed as functions of the characteristics of the particular innovation which was diffusing. Likewise, it might be possible to determine the relationship between the characteristics of the innovation, particularly its communicability (Rogers, 1962, p. 132), and the value of the sociometric influence parameters (CNEHBR and CMLORG). Fliegel and Kivlin (1966) have investigated the effects of the characteristics of innovations on the rate of diffusion.

The case of simulating the diffusion of a different innovation in a different community is the most complicated of all. The adjustments required in SINDI 2 in order to perform this analysis combine the adjustments discussed above for the two simpler cases.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

SINDI 2 is a general computer-based model which simulates the communication process by which individuals in a community are influenced to adopt an innovation through exposure to various types of persuasive messages: those carried by the mass media -- magazines, newspapers, radio programs, and television; and those encountered through interaction with adopters in pairwise meetings and at meetings of local organizations.

Associated with each individual is a set of fixed attributes which determine how the individual behaves during the processing of the model over time. These attributes, which do not change during the processing of the model, are as follows: probability of exposure to each issue of the various print media and to each program of the various electronic media; probability of attendance at meetings of each local organization; the time at which the individual entered the community; the time at which he began his work enterprise; and his raw resistance to adopting-innovation-X factor.

The communication linkages between individuals in the community are handled by SINDI 2 in the form of sociometric dyads, each dyad representing a potential one-way flow of information and influence between two individuals in the simulated population. The attributes

associated with each dyad include the identification numbers of the "namer" and the "named," the probability of daily interaction between the two individuals, and the credibility rating of the person named in the eyes of the namer. The "namer" is the respondent who has identified the person "named" as a discussion partner and/or opinion leader.

Associated with each simulated individual are five state variables which change during the processing of the simulation: a variable which assumes the value of 1.0 or 0.0 depending on whether or not the individual has become an adopter of the innovation, and four variables which cumulate the total amount of influence received from the print media, the electronic media, pairwise interaction with adopters and nonadopters in the individual's circle of discussion partners and opinion leaders, and interaction with adopters at meetings of local organizations.

The time-varying exogeneous variables in the model include the quantity of mass media messages carried by each of the mass media channels during each of the time periods and the number of meetings of each local organization during each time period.

At the beginning of a simulation run SINDI 2 presets certain individuals as innovators if they adopted before the specified starting time of the simulation run or as external adopters if they migrated into the community after the start of the simulation run but had adopted the innovation before they entered the community. Innovators are allowed to influence potential adopters from the start of the simulation run while external adopters can influence potential adopters only after they have entered the community. Potential

adopters who migrate into the community after the start of the simulation run may not be influenced by adopters within the community until after they have entered the community. Individuals who start their work enterprise after the start of the simulation run may be subject to influence from the various influencing sources during a specified persuasion period prior to starting their enterprise.

Although some of the attributes in the model are expressed as probabilities of exposure or interpersonal interaction, SINDI 2 is processed as a continuous, expected-value model rather than as a stochastic model which depends on the use of a random number generator to determine whether or not events take place. During each simulated time period SINDI 2 computes the expected value of influence on each potential adopter from innovation messages carried by the mass media (measured as square inches of print or minutes of program time) and from the interaction of these individuals with adopters among their circle of discussion partners and at meetings of local organizations. Interaction with nonadopters in an individual's circle of discussion partners reduces the amount of influence on him resulting from interaction with adopters. When the cumulative sum of influence from these various sources exceeds an individual's resistance to adopting the innovation, he becomes an adopter. Once an adopter, he is then capable of influencing others in the community to adopt.

SINDI 2 was first applied to simulate the diffusion of silos among 88 dairy farmers in a rural township in Brazil. Input data for the simulation model had been obtained by means of a survey conducted by the author in July, 1967. The survey provided the data

required on the attributes of individuals and the sociometric dyads required by the simulation model. A special application of multiple-partial regression analysis was used to predict the individual resistance factors as a function of attitudinal-economic variables with a part of the variance accounted for by the communication variables partialled out.

The author conducted a limited content analysis of some of the agricultural media in order to obtain rough measures of the quantity of innovation information which had been carried by these media during recent years. The survey also provided the real-world adoption data against which the simulated results could be compared.

The simulation was run for 36 half-year time periods beginning in 1957. A number of runs were made so that the eight tuning parameters could be adjusted to obtain the best-fit simulation run. At the macro level the simulated cumulative adoption curve produced by the best-fit simulation run was found to agree reasonably well with the empirical adoption curve. The Kolmogorov-Smirnov goodness-of-fit probability was 0.62. At the micro level, the correlation between the simulated adoption times and the empirical adoption times was 0.69 and, therefore, approximately 48 percent of the variance in empirical adoption times was explained by the simulation model. In this case, SINDI 2 performed as well as the general linear regression model which also explained 48 percent of the variance in empirical adoption times with ten attitudinal, economic, and communication variables.

SINDI 2 was also applied to the diffusion of forage grass plots in the same community with the tuning parameters set at the same

values determined in the best-fit run for silo diffusion. Application of SINDI 2 in this fashion represented a special case because it had been determined from the empirical data that forage grass plot diffusion proceeded at the same rate but with a lead time of 1.6 years. A straight multiple regression equation which was comprised of seven economic and communication variables was used to predict individual resistance factors. SINDI 2 explained approximately 26 percent of the variance in the empirical adoption times for forage grass plots, considerably less than was the case in silo diffusion but somewhat more than the 21 percent predicted by the linear regression model. The author suspects that much of the decrease in explained variance can be attributed to poorer reliability of the data on the adoption times for forage grass plots.

Specific Conclusions

On the basis of the results reported above, particularly on the application of SINDI 2 to the diffusion of silos, and on the basis of a series of sensitivity testing runs, the following conclusions may be stated. These conclusions obviously are tentative because they reflect the application of SINDI 2 to simulating only two very similar innovations in only one community.

Approximately 60 percent of the variation in the output of the simulation model (i.e. the simulated adoption times) was caused by the individual attitudinal and economic variables as introduced into the simulation through the resistance-to-innovating factor which was predicted from these variables. The remaining 40 percent of the variance in the simulated adoption times must have resulted from the

communication processes which were simulated by SINDI 2. Whether this is an accurate reflection of the real-world is hard to tell, but it seems reasonable.

In the best-fit simulation run, one of the tuning parameters was adjusted so that the degree of influence resulting from sociometric interaction was neither directly proportional to the raw frequency of interaction with other individuals nor independent of the raw frequency. This parameter assumed a value such that daily interaction with an adopter is only several times more effective in influencing an individual toward adoption than is infrequent interaction with an adopter. This was interpreted to be consistent with the notion that a new situation loses its impact on an individual upon repeated contact and also that individuals tend to treat others as units and thus be influenced by the fact that another individual has become an adopter.

Some improvement in the simulated output was noted when interaction with nonadopters in an individual's circle of discussion partners and opinion leaders was allowed to offset somewhat the influence on him from adopters in this circle. Again, this result was attributed to the tendency for individuals to be influenced not only by how frequently they interact with adopters but also by what percent of their acquaintances have adopted the innovation.

It was also found that the deletion from the simulation of the credibility rating of sociometric choices as measured by the ladder scale actually improved the ability of SINDI 2 to predict empirical adoption times. It was also noted that 80 percent of the sociometric choices for discussion partners were nonreciprocal. The percentage was even higher in the case of the choices for opinion leaders. The ability

of SINDI 2 to predict empirical adoption times decreased markedly in runs in which the sociometric choices were made reciprocal. These two results suggest that the best measure of source credibility was whether or not a per was chosen as a discussion partner or an opinion leader. It also suggests that the interpersonal channels for the flow of information and influence on technical innovations are quite nonreciprocal.

After runs were made with randomized sociometric data, it was concluded that the specific configuration of the communication network in this community accounted for approximately 15 percent of the explained variance in empirical adoption times. In other words, the position in which a person is located in the communication network can affect the time at which he becomes an adopter.

In the best-fit simulation run it was found that sociometric interaction with discussion partners and opinion leaders contributed 72 percent of the total influence on the simulated population; the print media, 24 percent; interaction with adopters at local meetings, 3 percent; and exposure to the one agricultural radio program 1 percent. Not too much weight should be attached to these particular values, however. The percent contribution to total influence from the interaction at local meetings and from messages carried by the radio was arbitrarily set by the author. Sensitivity testing on changes on these variables was not conducted. The sensitivity checking on the percent contribution from sociometric interaction and from the print media indicated that the simulated results were relatively insensitive to the inverse varying of these two parameters together within a range of approximately 15 percent.

It was found that that taking into account the time at which individuals migrated into the community and the time at which they started their work enterprises improved the simulation results. These may be important factors in the diffusion process in communities with unstable populations.

Finally, a run was made in which the quantity of mass media messages about the innovation was doubled in order to illustrate how such a model might be used for policy planning porposes. In this particular case the rate of diffusion increased somewhat but certainly not proportionally to the increase in the volume of innovation messages.

General Conclusions

A computer simulation model of the diffusion of an innovation through a social system has been designed and applied to a real-world diffusion system. The model appears to take into account the important aspects of the diffusion process: the flow of information and influence to potential adopters via the mass media and word-of-mouth communication as well as the resistance to innovating as a function of situational variables.

At the macro level the model reproduces the S-curve of the cumulative adoption curve very well and gives a reasonably good fit with the empirical curve. At the micro level the model explained approximately half of the variance in the empirical adoption times.

SINDI 2 is a dynamic model of a social diffusion process, and although it did not perform better than the linear regression model of innovation diffusion, the simulation model does facilitate

investigating the effects of changes in the controllable inputs to the diffusion system.

Suggestions for Future Research

More time could be spent in running more sensitivity testing runs for the diffusion processes reported in this study. As was indicated no runs were made to check the effect of varying the contribution of the radio channel and the interaction at meetings of the cooperative on the simulated output. Since there are eight tuning parameters it is difficult to exhaust all the possible combinations that could contribute to an improved best-fit run. However, the return on the investment in searching for better runs begins to diminish. Some thought might be given to implementing some automatic search techniques, although this is complicated by the fact that two criteria, one at the macro level and one at the micro level, are trying to be maximized.

Quite obviously, SINDI 2 should be applied to other diffusion systems in order to see if the results reported herein hold true. It should be noted that although it was found that interpersonal influence is not totally independent of the frequency of interaction, nevertheless the simulated output is not very sensitive to an adjustment in the sociometric interaction parameters which would make influence independent of the frequency of interaction (i.e., the case when CINFLU equals 0.0). This fact would facilitate applying SINDI 2 to diffusion systems for which empirical data has already been collected. There are many studies which have collected sociometric

data but did not obtain information on the frequency of interaction. Unfortunately, most of these studies lack the detailed information needed on the individual exposure probabilities to each of the mass media channels. Also, very few studies have collected any data on the quantity of innovation messages carried by the mass media channels. However, in some cases this data may be retrievable through the content analysis of library and archival copies of the print media. A content analysis of the electronic media is usually much more difficult to obtain.

A logical next step in research is to explore ways of extending SINDI to include aspects of certain diffusion processes not modeled by SINDI 2. An important extension of the model would be simulating the different strategies which might be utilized by an extension agent or a commercial agent.

Further modeling efforts might proceed in the direction of simulating the psychological processes associated with the different stages of the innovation decision-making process outlined earlier. This would probably require the concurrent work on improving the method of obtaining innovation decision protocols.

These latter suggestions for making the models more complicated have their drawbacks. The main drawback is that as the models become more complex, the number of tuning parameters increases with the result that it is more difficult to search for the best-fit solution. The tack taken in this study has been to study the simplest case first (i.e. a diffusion system in which outside extension agents and commercial agents did not have a significant role) in order to find

which relationships are important as well as to establish some tentative values for some of the empirical parameters for the relationships which do turn out to be important.

APPENDICES

APPENDIX A

SAMPLE RADIO SCRIPT FROM THE FARMER'S HOUR

The following is a sample script of one of the few "agricultural" radio programs which could be heard by farmers in Minas Gerais. At the time that the author contacted the producer of the program, there was no radio script available of a program which specifically mentioned dairy innovations. However, this script is an indication of the level and quantity of agricultural information disseminated by this radio series. Note that the proportion of air time devoted to disseminating information about agricultural practices is relatively low. However, the inclusion of popular music, jokes, and miscellaneous news items probably is necessary in order for the program to hold a sizeable audience.

[Rádio Inconfidência, Belo Horizonte, Minas Gerais
Farmer's Hour
Produced by Dr. João Anatólio Lima
Date: September 25, 1967
Hour: 8:00 to 8:35 p.m.]

Announcer: Farmer's Hour: the oldest agricultural program on Brazilian radio; organized by the agronomist Dr. João Anatólio Lima, who has been working for thirty years for the Brazilian farmer.

[Station identification, commercial, etc.]

Announcer: Today we are going to answer the following letters: Mrs. Felipina da Silva Valentim, Guarapari, Espírito Santo, and Mrs. Emilia S. Mebus, Cascatinha, Petropolis, Rio de Janeiro.

[Commercial]

Announcer: In the musical supplement we will focus on the LP "Três Duplas e Doze Modes" of Sabia. [Three duets and Twelve Folksongs.]

[Musical selection]

Announcer: The bees will finish off Brazil, a specialist on bees said the other day. Mr. Manoel Bernardes de Barros said that in ten years the African bees will dominate Brazil, because of their migratory instinct and their ability to reproduce quickly, and because of the lack of resources to control them. We believe the infestation of Brazil by African bees is possible. An example is the introduction of pardais [a bird] which, after it became used to the climate and environment, turned into a plague. As for the bees, there is a solution. One scientist proposed that if the flowers did not exist or ceased to produce nectar, the bees would disappear from the earth. Therefore, let us do away with flowers.

[Musical selection]

Announcer: Mrs. Felipina da Silva Valentim, from Guarapari, Espírito Santo, we received your letter. Thank you for the recipe you sent and also for telling us that you are a constant listener to our program. We are going to send you the recipe for making soap. As for the castor seed, we recommend the following per plant: manure, 10 kilos; wood ashes, 1 kilo; bone flower, 500 grams.

* * * * *

Modern times...modern hotel. A hotel manager in Paris decided to transform his hotel into a Men Only Hotel. Any gentleman who had to remain alone in Paris because his wife was on vacation or out of town, was welcomed at the hotel, where there were hotel maids who take care of his clothes, serve him home cooked food of his choice, etc. A modern hotel!

[Musical selection]

Announcer: A joke! It happened in a circus that a lion, who had just arrived and was not yet used to the local customs, asked another lion in the next cage, "Listen, buddy! Why is it that every Thursday the lady who owns the circus puts a flower on the meat she brings you?" And the other lion answered, "This is because I ate her husband about a year ago. He was the circus trainer, and I ate him exactly on a Thursday."

Announcer: Mrs. Emilia S. Mebus from Cascatinha, Petropolis, Rio de Janeiro, we received your letter. Here is our answer to your question: we examined the lemon tree leaf that you sent us. It had "Escama Virgula," which is not a reason for the lemon tree not producing fruit. Since the tree is only two years old, it might be good to fertilize it with the following: manure, 15 kilos; superphosphate, 500 grams; potassium chloride, 100 grams.

[Station identification, commercial, etc.]

Announcer: News from the School of Veterinary. Dr. José Cisne Uchoa de Aquiño, veterinarian of the National Agrarian Institute in Ceará, is in Belo Horizonte, to study at the School of Veterinary. He will be working under Professor Francisco Megale, chairman of the animal clinic and a specialist in physiopathology of reproduction. Dr. José Aquino will remain in Belo Horizonte until December of next year.

[Musical selection]

Announcer: Dear farmer: the absence of organic matter in ideal quantities is very common in some regions and is due largely to the inappropriate work done by farmers and to the effect of erosion. Another reason for the lack of organic matter is the "fire," when harvest residues are burnt by farmers. It is necessary to understand clearly that it is impossible to practice soil conservation and to improve the production of the land if we do not return to the land regularly its organic matter.

* * * * *

The "national wheat," which is never enough praised: It is worthwhile to remember that on August 12, 1937 (thirty years ago), Rio de Janeiro and São Paulo newspapers published this news: "President Getúlio Vargas signed a law that authorizes the executive to implement the cultivation of wheat in Brazil, determining that the Ministry of Agriculture should organize five experimental stations, forty areas for seed reproduction, and a central experimental laboratory to study the manufacture of bread." Thirty years have passed and Brazil is still importing wheat in large quantities, so that the people can eat bread. There was a Minister of Agriculture not long ago who, when he took office, launched the slogan: "Our bread--with our wheat." Things remained only as slogans.

[Station identification, commercial, etc.]

Announcer: Until tomorrow, same time, God willing.

APPENDIX B

A FIELD INTERVIEW WITH A DAIRY FARMER IN CONCEIÇÃO DO RIO VERDE

A month after the field survey the author returned to Conceição do Rio Verde to conduct informal, tape-recorded field interviews with several of the original respondents in order to obtain more insight into the innovation decision-making process. The interviews were conducted by a Brazilian interviewer with the author sitting in and also interjecting a few questions. These efforts to obtain in-depth "decision protocols" were not totally successful because of insufficient time to perfect the technique. Nevertheless, the interviews did provide certain insights into the diffusion process which did not come through in the formal interview schedules.

Excerpts from one of the more successful interviews follow below. The interview was conducted with a typical dairy farmer. He owned 40 cows (about average in Conceição), he was 32 years old, had moved into the community after his marriage about eight years before, had nine years of schooling, and was about average in exposure to the agricultural news media. Several points emerge from the interview. First, the interviewee was very much influenced by friends and relatives to adopt various innovations. Second, rural credit can play an important role in the decision to adopt the more expensive innovations. Third, the interviewee suggested that many farmers made no substantive

distinction between the use of sugar cane as a forage grass and the use of the newer varieties of forage grass. Thus the wording in the formal questionnaire with respect to the adoption of a forage grass plot should have been more specific. Fourth, the adoption of certain innovations is contingent on the adoption of other innovations. For example, this interviewee did not consider adopting the use of tick pesticide until after he began using a Dutch breeding bull to improve his herd.

. . . . . .

Int:[1] You've been using a silo for five years; how long ago did you hear of silos?

Res: Oh, some nine or ten years ago.

Int: Now this means that it was five years from the time you first heard of silos to the time you began to use one, wasn't it? And where did you obtain information?

Res: I had a brother-in-law who had a silo and I saw the way he used to fill it. It looked good, and it seemed to give good results. When I first built a silo, I didn't take a loan for it because I didn't know that there was a loan available from the Bank of Brazil. At that time I only had taken a loan at this bank to improve coffee; I didn't know that the loan for building a silo was available. I had already wanted to have my own silo at that time, but I was not in a financial position to build one, you know what I mean? My financial position improved, and the period of five years elapsed, then I built a silo, but on my own without any financing. The first silo I built held 28 tons; the second one, built last year holds only 20 tons.

. . . . . .

Int: Would you tell us your source of information about silos?

Res: Before I married, I lived on my father's farm. There nobody used silos. After I got married and came up here I learned about silos on my brother-in-law's farm.

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[1] "Int:" indicates Interviewer; "Res:" indicates Respondent.

Int: Did he already have a silo?

Res: Yes. He did not give me information on how to build the silo, but he showed me that it was giving good results, as in fact it was. For example, take sugar cane [spoken of here as a forage grass crop in contrast to silage]: it's very good food, but silage has the advantage over sugar cane during the frost season. We can fill the silos during the rainy season. Then if we have lots of frost, we will still have food to give the cattle. Isn't that true? But the same thing doesn't happen with sugar cane. If there is very bad weather, as we have had here, frosty, the whole crop freezes up, and after the sugar cane is frozen, it's not much good anymore.

. . . . . .

Int: Do you know anybody here who has a trench silo?

Res: Yes.

Int: Does he say anything about his silo?

Res: He says that the silo is very cheap, easy to fill up also, you know....But the silage spoils more easily. It does not keep as long as silage in the cistern silo. The trench silo is cheaper, easier to build since you only need to dig a ditch and a wall like this. There are many who don't even cement those walls; they only put bricks. But this way the silage spoils quickly, espcially in those parts that are exposed to humidity. The cistern silo, on the other hand, keeps silage longer.

. . . . . .

Int: You use forage grass plots, don't you?

Res: The forage grass plot that I use is sugar cane and Napier grass. I tried the Guatemala grass also, but I found it weak [non-resistant to frost]. The Guatemala gives a lot of output, but it's very weak. The Napier is a good grass, but it has one disadvantage: during the frost it also freezes up. It is a good grass in the rainy season -- it's always green....

Int: Is sugar cane considered a forage grass?

Res: I think it is in this region.

Int: For how many years have you used forage grass plot?

. . . . . .

Res: I have been using forage grass plot for 16 years, but when I was farming at my father's farm, I already had sugar cane. This means that I knew about sugar cane there at my father's farm.

Int: What were the factors that led you to use forage grass plots?

Res: The first factor is that today a man must have forage grass, even if he doesn't want to, because during the dry season our pastures dry up, don't they? The dry season with the frost means that if we don't have forage grass or silos for the months from July to November, when the rains begin, the cattle get restless and sometimes die. We've been loosing quite a lot of cattle.

Int: What is the price, more or less, for planting a forage grass plot?

Res: It's quite expensive today because one has to plant the whole plot and one has to clean the field up when the plot has matured. The Napier grass, for example, doesn't give much trouble after it is matured. But the sugar cane is another thing. It needs four or five cleanings every year so that it won't die out.

Int: Did you make any loans for forage grass plots?

Res: No.

Int: How long have farmers here in this area used forage grass plots?

Res: In the old times they only planted sugar cane here -- these farms here had sugar cane mills. They used sugar cane for sugar, for pinga [a kind of whiskey], and then the farmers began also to feed the cattle with the sugar cane that was left over. Other people saw the results and began to do the same, so that today most farms here still use sugar cane for feeding cattle. Every farm has sugar cane. Napier began to appear later on in the state of São Paulo. That's where they began to use it. Then it came slowly to this area here.

. . . . . .

Int: Why do you use Napier?

Res: Sometimes I mix Napier with sugar cane, and also the Napier that I have here is good for the rainy season. I give my cattle Napier all year round because I have little pasture. This makes stronger cattle and a better average of milk. I have a pasture of 80 hectares [one hectare equals 2.47 acres] where I have to keep an average of 40 cows. I would need some 15 more hectares of pasture if I were going to keep the cattle in the pasture alone. But with forage grass and the silo, I can feed the 40 cows in the 80 hectares all year round.

. . . . . .

Int: Was your milk production the same before you began to use forage grass and the cistern silo?

Res: No. Before, the average was less. After I built the silo and began to use the forage grass, my average went up. When I came here there were no cattle on this farm. The farm belonged to my wife and she rented it to her brothers because she was a minor and she was studying. When I came up here my average was 100 liters of milk per day on the farm. After I built the silo and began using forage grass, I started getting 200 liters of milk per day on a yearly average.

Int: Do you have a forage grass chopper?

Res: Yes, I do.

Int: How did you buy it?

Res: Through the Bank of Brazil -- both the chopper and the motor to run it....

. . . . . .

Int: When did you first hear about tick spray?

Res: I first heard a neighbor talking about it -- that he had bought it and that he had a bath and a shower to apply it. I saw that his cattle were much better. Then I began to use tick spray.

. . . . . .

Int: What were the factors that led you to use tick spray?

Res: The first factor was the cattle. For example, we had mixed cattle, but we didn't use spray with these cattle, because they do not require it. But when you have Dutch cattle, you have to take better care of your cattle, because the breed is better, and if you don't have a bath on your farm, there is no use in dealing with the Dutch cattle -- they become weak. If I didn't have the bath, I don't know whether I would still deal with Dutch cattle. Another of the first factors was this: I began by putting a Dutch bull here to improve my cattle; therefore, I had to use tick spray. Then when the Dutch cattle came -- this is a weaker breed and the bath is needed, especially during the dry season.

Int: And where do you get the solution for your bath?

Res: From the cooperative.

. . . . . .

Int: When you build a bath is it necessary to ask for a loan -- how much does it cost today to build a bath?

Res: Today, the Bank of Brazil finances everything for building a bath. But this one here that I use was not built by us. It was built by my father-in-law; that means it is an old bath.

Int: Didn't you borrow any money to build it? You didn't take any loan?

Res: No, this bath is on my father-in-law's farm, and I take my cattle there.

Int: Here on your farm do you have a bath?

Res: Here I only have a hand sprayer. Now I take the cattle to the other farm. Today it does not belong any more to my father-in-law, it belongs to my brother-in-law who lives there. My father-in-law left, and the farm is now my brother-in-law's But the bath still belongs to the society and it is used by all brothers. It is easier for me to take the cattle there than to build a bath, borrowing money from the Bank of Brazil, especially if I consider the size of my land. The number of calves that I have do not require a bath so it is easier for me to take my cattle to the other farm.

. . . . . .

Int: When did you first hear about mineral salts.

Res: When I left school my father was already using them. I [illegible] o deal with cattle, and when I took my own cows, I began [illegible] the mineral salts, which are necessary because of the lack [illegible]erals in the pastures. Sometimes our pastures today are not [illegible]d as they used to be. Today the pastures are already wo[illegible] and there is lack of mineral salts which the cattle need.

Int: So you adopted mineral salts at the same time that you [illegible] bath 16 years ago? Where did you obtain information a[illegible] salts?

Res: I heard, for example, from the salesman. Today many [illegible] factories have many salesmen. Several of the factori[illegible] make mineral salts are good, some are bad, and one do[illegible] know anything. They come and they offer you mineral [illegible] and you know about it. They say that some have phospho[illegible] others don't -- but you never know and you have to buy whatever is offered.

Int: Which one do you use presently?

Res: The one from Sivan.

Int: And do you get these products directly from the salesm[illegible]

Res: No. We get them now-through the cooperative. Salesmen always come by to leave them at the cooperative. We buy from the cooperative.

Int: Do you have other sources of information?

Res: We get information through salesmen and also in conversation with other farmers. Besides there are always the meetings at the cooperative.

Int: The meetings at the cooperative?

Res: Yes, there are always lots of subjects in meetings, aren't there?

Int: Also the veterinarians gave information about mineral salts, didn't they?

Res: Yes, and also here in Caxambú, there was a meeting some eight years ago. Some government officials came up here and talked about all this. About mineral salts, about forage grass.

. . . . . .

Int: Well -- and what influenced you to use mineral salts?

Res: What influenced me more was not the salesmen's advertisements, but a neighbor who was using mineral salts. He was getting very good results. Even my own cousin -- he was one who influenced me to use mineral salts.

SELECTED BIBLIOGRAPHY

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Abelson, Robert P., and Alex Bernstein. "A Computer Simulation Model of Community Referendum Controversies." Public Opinion Quarterly, 27 (Spring, 1963), 93-123.

Abelson, Robert P., and J. D. Carroll. "Computer Simulation of Individual Belief Systems." American Behavioral Scientist, 8 (May, 1965), 24-30.

Abelson, Robert P. "Simulation of Social Behavior." The Handbook of Social Psychology. Vol 2. 2nd ed. Edited by Gardner Lindzey and Elliot Aronson. Reading, Mass.: Addison-Wesley Pub. Co., 1968.

Amstutz, Arnold E. Computer Simulation of Competitive Market Response. Cambridge, Mass.: The MIT Press, 1967.

Bailey, Norman T. J. The Mathematical Theory of Epidemics. London: Charles Griffin, 1957.

Barnett, H. G. Innovation: The Basis of Cultural Change. New York: McGraw-Hill Book Co., 1953.

Bartholomew, David J. Stochastic Models for Social Processes. London: John Wiley and Sons, 1967.

Bartlett, M. S. Stochastic Population Models in Ecology and Epidemiology. London: Methuen and Co. Ltd., 1960.

Blalock, Hubert M. Social Statistics. New York: McGraw-Hill Book Co., 1960.

Bowden, Leonard W. Diffusion of the Decision to Irrigate. Research Paper 97. Chicago: Department of Geography, University of Chicago, 1965.

Brown, Lawrence A. Models for Spatial Diffusion Research: A Review. Technical Report Number 3, Spatial Diffusion Study. Evanston, Ill.: Department of Geography, Northwestern University, 1965.

_____. "Diffusion Dynamics: A Review and Revision of the Quantitative Theory of the Spatial Diffusion of Innovation." Unpublished Ph.D. dissertation, Northwestern University, 1966.

_____. Diffusion Processes and Location: A Conceptual Framework and Bibliography. Philadelphia: Regional Science Research Institute, 1968.

Bucher, Rue, Charles E. Fritz, and E. L. Quarantelli. "Tape Recorded Interviews in Social Research." American Sociological Reivew, 21 (June, 1956), 361-64.

Coleman, James S. Introduction to Mathematical Sociology. New York: The Free Press, 1964.

Coleman, James S., Elihu Katz, and Herbert Menzel. Medical Innovation: A Diffusion Study. Bobbs-Merrill Paperback. Indianapolis: Bobbs-Merrill Co., Inc., 1966.

Corlett, T., and D. W. Osborne. The Development of Reading Frequency Scales. London: Institute of Practitioners in Advertising, 1966.

Cox, Donald F. "Risk Handling in Consumer Behavior -- an Intensive Study of Two Cases." Risk Taking and Information Handling in Consumer Behavior. Edited by Donald F. Cox. Boston: Division of Research, Harvard Business School, 1967.

Daley, D. J., and D. G. Kendall. "Stochastic Rumours." Journal of the Institute of Mathematics and Its Applications, 1 (1965), 42-55.

Deutschmann, Paul J. I: "A Machine Simulation of Attitude Change in a Polarized Community." II: "A Machine Simulation of Information Diffusion in a Small Community." III: "A Model for Machine Simulation of Information and Attitude Flow." San Jose, Costa Rica: Programa Interamericano de Informacion Popular, 1962. (Three mimeographed papers.)

Deutschmann, Paul J., and Orlando Fals Borda. Communication and Adoption Patterns in an Andean Village. San Jose, Costa Rica: Programa Interamericano de Informacion Popular, 1962.

Dichter, Ernest. "How Word-of-Mouth Advertising Works." Harvard Business Review, 44 (Nov.-Dec., 1966), 147-167.

Dodd, Stuart C., and William S. Peirce. "Three Momental Models for Predicting Message Diffusion." Journal of Broadcasting, 11 (Fall, 1967), 339-54.

Emery, F. E., and O. A. Oeser. Information, Decision and Action: Psychological Determinants of Changes in Farming Techniques. Melbourne, Australia: University of Melbourne Press, 1958.

Fals-Borda, Orlando. Peasant Society in the Colombian Andes. Gainc[illegible], Fla.: University of Florida Press, 1955.

Festinger, Leon. A Theory of Cognitive Dissonance. Palo Alto, Calif.: Stanford University Press, 1957.

Fliegel, Frederick C., and Joseph E. Kivlin. "Attributes of Innovations as Factors in Diffusion." American Journal of Sociology, 72 (November, 1966), 235-48.

Fonseca, Luiz. "Information Patterns and Practice Adoption Among Brazilian Farmers." Unpublished Ph.D. dissertation, University of Wisconsin, 1966.

Griliches, Zvi. "Hybrid Corn: An Exploration in the Economics of Technological Change." Econometrica, 25 (October, 1957), 501-22.

Gullahorn, John T., and Jeanne E. Gullahorn. "The Computer as a Tool for Theory Development." The Use of Computers in Anthropology. Edited by Dell Hymes. The Hague: Mouton and Co., 1965.

Hägerstrand, Torsten. "Quantitative Techniques for Analysis of the Spread of Information and Technology." Education and Economic Development. Edited by C. A. Anderson and M. J. Bowman. Chicago: Aldine Pub. Co., 1965.

_____. "On the Monte Carlo Simulation of Diffusion." Quantitative Geography. Part I: Economics and Cultural Traits. Edited by William L. Garrison and Duane F. Marble. Studies in Geography No. 13. Evanston, Ill.: Department of Geography, Northwestern University, 1967.

_____. Innovationsforloppet ur Korologisk Synpunkt. Lund, Sweden: Gleerup, 1953. Translated by Alan Pred as Innovation Diffusion as a Spatial Process. Chicago: University of Chicago Press, 1968.

Hanneman, Gerhard J., and Tom W. Carroll. SINDI 1: Simulation of Information Diffusion in a Peasant Community. Technical Report No. 7 of the Project on Diffusion of Innovations in Rural Societies. East Lansing, Mich.: Department of Communication, Michigan State University, 1969.

Hanneman, Gerhard, J., Tom W. Carroll, Everett M. Rogers, J. David Stanfield, and Nan Lin. "Computer Simulation of Innovation Diffusion in a Peasant Village." American Behavioral Scientist, (July, 1969).

Hapgood, David, ed. Policies for Promoting Agricultural Development. Report No. c/65-3. Cambridge, Mass.: Center for International Studies, Massachusetts Institute of Technology, 1965.

Hartman, John J. Annotated Bibliography on Simulation in the Social Sciences. Iowa Agricultural and Home Economics Experiment Station, Iowa State University, 1966.

Hermann, Charles F. "Validation Problems in Games and Simulation with Special Reference to Models of International Politics." Behavioral Science, 12 (May, 1967), 216-31.

Herzog, William A., J. David Standfield, Gordon C. Whiting, and Lynne Svenning. Patterns of Diffusion in Rural Brazil. Diffusion of Innovations Research Report 10. East Lansing, Mich.: Department of Communication, Michigan State University, 1968.

Hodgson, R. E., and O. E. Reed. Manual de Lacticínios para a America Tropical. ("Manual for Dairy Cattle in Tropical America.") Washington, D. C.: International Cooperation Administration, 1961.

Karlsson, George. Social Mechanisms. Glencoe, Ill.: The Free Press, 1958.

Katz, Elihu. "The Two-step Flow of Communication: An Up-to-date Report on an Hypothesis." Public Opinion Quarterly, 21 (Spring, 1957), 61-73.

_____. "The Diffusion of New Ideas and Practices." The Science of Human Communication. Edited by Wilbur Schramm. New York: Basic Books, Inc., 1963.

Katz, Elihu, Martin L. Levin, and Herbert Hamilton. "Traditions of Research on Diffusion of Innovations." American Sociological Review, 28 (April, 1963), 237-53.

Kiviat, P. J. Digital Computer Simulation Modeling Concepts. Memorandum RM-5378-PR. Santa Monica, Calif.: Rand Corporation, 1967.

LaPiere, Richard T. Social Change. New York: McGraw-Hill Book Co., 1965.

Levine, Robert, ed. Brazil: Field Research Guide in the Social Sciences. New York: Columbia University, Institute of Latin American Studies, 1966.

Linton, Ralph. "Diffusion." In his The Study of Man. New York: Appleton-Century-Crofts, 1936.

Lionberger, Herbert F. The Diffusion of New Ideas and Practices. Ames, Iowa: Iowa State University Press, 1960.

Loomis, Charles P., Julio O. Morales, Roy A. Clifford, and Olen E. Leonard. Turrialba. Glencoe, Ill.: The Free Press, 1953.

McCracken, Daniel D. "The Monte Carlo Method." Scientific American, 192 (May, 1955), 90-96.

Mason, Rogert G. "The Use of Information Sources in the Process of Adoption." Rural Sociology, 29 (March, 1964), 40-52.

Mason, Robert G. and Albert N. Halter. "The Application of a System of Simultaneous Equations to an Innovation Diffusion Model." Social Forces, 47 (December, 1968), 182-95.

Mattoso, J. Melhoramento do Rebanho Leiteiro. ("Dairy Herd Improvement.") Belo Horizonte, Brazil: Convênio Ministério da Agricultura, 1966.

Metheringham, Richard A. "Measuring the Net Cumulative Coverage of a Print Campaign." Journal of Advertising Research, 4 (January, 1964), 23-28.

Morris, John. Nonparametric Statistics. Technical Reports Nos. 40 44. East Lansing, Mich.: Computer Institute for Social Science Research, Michigan State University, 1967.

Mosher, Arthur T. Technical Cooperation in Latin-American Agriculture. Chicago: The University of Chicago Press, 1957.

_____. Getting Agriculture Moving. New York: Frederick A. Praeger, Inc., 1966.

Mundim, Libencio Borges. Sub-Projecto Melhoramento da Pecuária em Minas Gerais. ("Sub-project for the Improvement of Animal Husbandry in Minas Gerais.") Belo Horizonte, Brazil: Projecto do Comercializacao Agricola de Minas Gerais, 1966.

Myren, Delbert T. Bibliography: Communications in Agricultural Development. Mexico City: Rockefeller Foundation, 1965.

Naylor, Thomas H., Joseph L. Balintfy, Donald S. Burdick, and Kong Chu. Computer Simulation Techniques. New York: John Wiley and Sons, Inc., 1966.

Newell, Allen, and H. A. Simon. "GPS: A Program That Simulates Human Thought." Computers and Thought. Edited by Edward A. Feigenbaum and Julian Feldman. New York: McGraw-Hill Book Co., Inc., 1963.

Nunes, William da Silva, and Thyrso Machado. Calendário Anual das Atividades da Exploração Leiteira. ("Annual Calender of the Activities of Dairy Herd Experimentation.") Belo Horizonte, Brazil: Associação do Crédito e Assistência Rural, 1965.

Pitts, Forrest R. "Problems in Computer Simulation of Diffusion." Papers and Proceedings of the Regional Science Association, 11 (1963), 111-19.

_____. HAGER III and HAGER IV: Two Monte Carlo Computer Programs for the Study of Spatial Diffusion Problems. Technical Report No. 4, Spatial Diffusion Study. Evanston, Ill.: Department of Geography, Northwestern University, 1965.

_____. MIFCAL and NONCEL: Two Computer Programs for the Generalization of the Hagerstrand Models to an Irregular Lattice. Technical Report No. 7, Spatial Diffusion Project. Evanston, Ill.: Department of Geography, Northwestern University, 1967.

Pool, Ithiel de Sola, Robert P. Abelson, and Samuel L. Popkin. Candidates, Issues, and Strategies. Rev. ed. MIT Paperback Series. Cambridge, Mass.: The MIT Press, 1965.

Rainio, Kullervo. A Stochastic Model of Social Interaction. Copenhagen: Munksgaard, 1961.

Rapaport, Anatol. "Nets with Reciprocity Bias." Bulletin of Mathematical Biophysics, 20 (1958), 191-201.

Rogers, Everett M. Diffusion of Innovations. New York: Free Press, 1962.

_____. Bibliography on the Diffusion of Innovations. Diffusion of Innovations Research Report 6. East Lansing, Mich.: Department of Communication, Michigan State University, 1967.

_____. Supplement to the Bibliography on the Diffusion of Innovations. Diffusion of Innovations Research Report 6a. East Lansing, Mich.: Department of Communication, Michigan State University, 1968.

_____. Modernization Among Peasants: The Impact of Communication. New York: Holt, Rinehart and Winston, 1969.

Rogers, Everett M. with F. Floyd Shoemaker. Communication of Innovations: A Cross-Cultural Approach. New York: Free Press of Glencoe, (forthcoming).

Salcedo, Rodolfo. "A Communication Model of Modernization." Unpublished Ph.D. dissertation, Michigan State University, 1968.

Schultz, Theodore W. Transforming Traditional Agriculture. New Haven: Yale University Press, 1964.

Stanfield, J. David. "The Correlates of Community Economic Development in Brazil." Paper presented at the annual meeting of the Rural Sociological Society, Boston, Mass., August, 1968.

_____. Interpersonal Trust and Modernization in Rural Brazil. Technical Report No. 9 of the Project on Diffusion of Innovations in Rural Societies. East Lansing, Mich.: Department of Communication, Michigan State University, 1968.

Tax, Sol. Penny Capitalism. Chicago: University of Chicago Press, 1953.

Tiedeman, Clifford E., and Carlton S. Van Doren. The Diffusion of Hybrid Seed Corn in Iowa: A Spatial Simulation Model. Technical Bulletin 13-44. East Lansing, Mich.: Institute for Community Development and Services, Michigan State University, 1964.

United States of America Standards Institute. USA Standard FORTRAN. USA Standard X3.9-1966. New York: United States of America Standards Institute, 1966

Wellin, Edward M. "Water Boiling in a Peruvian Town." Health, Culture and Community. Edited by Benjamin Paul. New York: Russell Sage Foundation, 1955.

Whiting, Gordon C. William A. Herzog, Gustavo M. Quesada, J. David Stanfield, and Lytton Guimaraes. Innovation in Brazil: Success and Failure of Agricultural Programs in Seventy-six Minas Gerais Communities. Diffusion of Innovations Research Report 7. East Lansing, Mich.: Department of Communication, Michigan State University, 1968.

Wolpert, Julian. "A Regional Simulation Model of Information Diffusion." Public Opinion Quarterly, 30 (Winter, 1967), 597-608.