A COMPUTER SIMULATION OF INFORMATION DIFFUSION IN A PEASANT COMMUNITY

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GERHARD J. HANNEMAN

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ABSTRACT

A COMPUTER SIMULATION OF INFORMATION DIFFUSION IN A PEASANT COMMUNITY

By

Gerhard J. Hanneman

SINDI 1 is a Monte Carlo computer model which simulates the diffusion of information in a peasant community. The runs reported here use data collected in Colombia as a means of parameter estimation and for validity comparisons.

The diffusion of an innovation is the spread over time of a new idea through a social system. Information about the actual innovation is transmitted through communication channels in the form of messages representing the idea of the innovation object. SINDI 1 simulates this process of diffusing information about the actual innovation through a social system to create awareness about the innovation. The model does not presume adoption of the innovation by the receiver of the information.

In SINDI 1 there are two external channels through which innovation information enters, one representing an extension agent, the other representing the school teacher who has an urban, rather than local, orientation. Mass media channels are not important in SINDI 1 because the villagers are illiterate and not exposed to agricultural radio programs. Individuals in a community can be divided into cliques of highly interacting members, with local word-of-mouth messages flowing more frequently within cliques. In the model, 56 peasants were divided

into four interacting cliques and one group of isolates. There is a 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. There are nine potential tellers in SINDI 1, each of whom cannot contact others until he has received information about an innovation (become a "knower"). Prior to each run, SINDI 1 preassigns some individuals as knowers if they were knowers before the start of simulated time.

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 each external channel source per time period; (3) the number of contacts allowed a teller once he becomes a knower; (4) the probability of a nonknower becoming a knower through any external channel source; (5) 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 routine handles the monitoring tasks for the simulation: it executes the main DO loops and calls the other subroutines. The first subroutine, INPUT, reads in the parameters and initializes arrays for the beginning of a run and a time period. The next routine, EXTMES, is the external message section. In this routine 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 and the channel source of the message for a particular contact. A randomly generated decimal 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 nonknower. Subroutine TELCON is the teller contact section. It 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. Subroutine OUTPUT prints out a summary of the information transfer events for the simulation. Subroutine RANDOM is random number generator based on an extension of Lehmer's rule which provides random integer subject numbers and random decimals between zero and one.

Results of different series of runs of SINDI 1 were discussed. The runs simulated diffusion of information about a weed spray to Colombian peasants. The results have so far failed to replicate both the slow initial curve rise and the high number of knowers at the top of the "S" curve of the reality data.

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Director of Thesis

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CHAPTER I

INTRODUCTION

THE PROBLEM

The central problem of this study is: "Can we validly simulate part of the diffusion of innovations process by computer modeling?" Or, in other words, is it possible to abstract from the many variables affecting innovation diffusion, model those abstracted variables dynamically, and obtain results which closely approximate real-world data?

Rationale for Simulating Diffusion Processes

There are three main reasons (in this case) for using a simulation model to study information diffusion of innovations: (1) to refine the technique of computer simulation for studying the diffusion process by actually programming a model usable by potential diffusion researchers; (2) to examine the interaction of specific diffusion variables and the effects when those variables are manipulated for a part of the process; (3) on the basis of the computer simulated process and output, possibly revise relevant (or add to) generalizations of diffusion theory.

Innovation diffusion theory is generally well-formalized and can, for the purpose of this paper, be divided into two broad approaches.* The first approach is that of spatial diffusion theory--characteristic of the work of Hägerstrand (1967); the other approach is that of

*However, diffusion theory, unrelated to innovations, is also used in mass media research to analyze the dissemination of news, and has been used by biologists to study the spread of communicable diseases (epidemiology).

communication-sociological diffusion theory characteristic of the work of Rogers (1969b). While the former researcher studies spatial variables (i.e., those dealing with relationships based on proximity) in the diffusion process, the latter researcher studies communication and social system variables (e.g., message channels, norms, roles, etc.). Both, however, are interested in the process by which new ideas diffuse or spread to individuals; they deal with variables representing the individual's characteristics, and the communication process's characteristics. The spatial diffusion theorists also study proximity variables, and determine probabilities of interpersonal contact based on these variables. The communication diffusion theorists do not generally deal with proximity probabilities, but with social system variables affecting the communication process and the individual's acceptance of the new idea, and with variables describing the characteristics of the innovation.

Researchers in each of the above areas manipulate many different independent variables in order to measure and/or predict the dependent variables of the rate of adoption of an innovation by an individual, and/or the rate of diffusion of an innovation in a social system (such as a peasant village) or in a geographical area. Thus, depending on his approach, the diffusion researcher uses either cartography or sociology, plus methodological tools such as sociometry and surveys, with the statistics of description and inference. Utilizing these methods, the researcher measures and makes inferences based on the population observed and the innovation diffusion studied. What he lacks, however, is an adequate method for modeling the behavior he wishes to measure or, in the case of a change agent, an adequate model which he can use to predict the effects of diffusing a particular innovation. Verbal models have the disadvantages of being overdetailed and lacking dynamism. Mathematical models and hand simulations have two drawbacks: if many variables are involved, the hand simulation is very tedious and time consuming; if certain mathematical equation systems are not known or unavailble to the model builder he is behooved to apply the mathematical models for which he knows solutions are available (this criticism is applicable to computer simulation,in a sense, because the software and hardware also impose constraints on the model's completeness). Computer simulation provides a method of modeling which incorporates time changes, i.e., it is not a static description of a process unavailable to manipulation and precise value changes like the verbal model; it can manipulate complex variable relationships with speed, restricted only by the inability of the model builder to state theoretic assumptions in a computer language.

Computer simulation has been largely ignored by the diffusion researchers in the communication-sociological tradition, but widely recognized and accepted by spatial diffusion theorists.* One of the reasons for this difference is probably because spatial diffusion variables are highly mathematical and more amenable to simulation than the communication-sociological counterparts. Computer programming languages and practices favor quantification of statements due to the computer's numerical-based operation.

*Of the over 1500 diffusion studies in the Diffusion Documents Center at Michigan State University, less than 25 are diffusion simulations--and most of these are spatial diffusion simulations. A review of computer simulation in the diffusion field may be found in Stanfield, Lin, and Rogers (1965).

Thus, computer simulation offers diffusion researchers the advantage of being a dynamic analog of theory, easily modeling complex and lengthy real time processes in shorter simulated time. If, through repeated comparison of simulated results with real data, and subsequent refinement of the model and more comparisons we can develop a valid analog,* then the model becomes a useful tool as a predictor: this is the first reason for using a simulation model. A user of the model would be able to predict the direction of an information diffusion process (the model presented here simulates the <u>information</u> aspect of the diffusion process), and even the effects of using different communication channel combinations for the same innovation.

In the formal, analogic model to be described here we will abstract from a part of general diffusion theory that deals with creating knowledge of an innovation among individuals. This knowledge is created by the systematic spread of information about the new idea through communication channels. Of the variables which might be considered in the information diffusion stage, only four (which will be defined in the next section) are considered: opinion leadership, clique structure, channel structure, and amount of knowledge. We will simulate the dynamic interaction of these variables to produce simulated data of the amount of knowers of the information over a certain amount of time; in this way we can judge the effectiveness of our variable's data "settings" and interaction. Unfortunately, as Kaplan (1964) points out in <u>The Conduct of Inquiry</u>,

*Reliability is inherently assured in a simulation by the use of computer programs. Computer simulations are reliable to the extent that the computer processes the program statements without error (e.g., an error could occur if an electronic component was faulty within the computer causing a program statement to be misinterpreted).

in the behavioral sciences data from models will never closely approximate reality because of the huge number of variables to be considered in any human interaction. The advantage of computer modeling is that we can include many variables (practical limitations permitting), to determine accurately what effect those chosen variables have on the process being studied.

Finally, if we are certain that our model is a valid analog (through constant comparisons between simulated results and other criteria) then we may determine in the course of modeling that one or more of the variables really has little effect in the information diffusion process. On the other hand, through the additional use of inferential statistical techniques we may determine that certain manipulated variables have greater effect than previously supposed. If these effects were consistent across many innovations then we might refine diffusion theory to account for them. Part of the theoretic rationale for variables being modeled here, represents a synthesis of variables from the two diffusion approaches previously defined. By combining a study of the interaction of variables from two areas, we have another way to refine and arrive at a broader diffusion of innovations theory.

THEORIES OF INFORMATION DIFFUSION

Rogers (1969a, p. 1-9) emphasizes that social change is an effect of communication. Indeed, change in cross-cultural settings is virtually impossible to effect without communication. It is this assumption about communication which underlies diffusion theory for both communication-sociological diffusionists and the spatial diffusionists. The significance of communication, especially via interpersonal channels, in underdeveloped countries is recognized in the proposed simulation.

Social change, according to Rogers (1969a, p. 1-9) can be viewed in three sequential steps: (1) invention, the process by which new ideas are created and developed; (2) diffusion, the process by which new ideas are transmitted through communication channels among members of a social system; (3) consequences, the changes that occur as the result of the introduction of the innovation in the social system.

The diffusion of information about an innovation, then, is message transmission about new ideas through communication channels to the members of a social system. An innovation is an idea, practice or object perceived as new by the individual. A social system is a group of individuals held together by a commonly shared goal (e.g., to be members of a village). Communication channels are the means by which innovation messages are transmitted to the social system members. Inherent in any definition of the process of communication is time; time is central to diffusion in terms of when innovation decisions (decisions deciding to adopt or reject the innovation) are made by individuals in the target system.

Rogers (1969a, p. 1-36) conceptualizes four main functions of an innovation decision process (the process whereby an individual decides whether or not to adopt the innovation): (1) knowledge--first information about the new idea; (2) persuasion--attitude formation and change as a result of the information; (3) the decision--actual adoption or rejection of the new idea on the basis of the newly formed attitude; and (4) confirmation--justification of the decision made by the individual. The computer model described here simulates the first function: creating knowledge about the new idea.

Another computer model, SINDI 2, operationalized by Carroll (1969), extends this simulation model to include the last three functions of the innovation decision process. That is SINDI 2 simulates not only diffusion of information, but also the influence process which leads people to adopt innovations. Therefore, our model could be considered more an aggregate simulation model of interpersonal diffusion processes only, and SINDI 2, a model of the interpersonal diffusion processes and "individual" decision processes.

An Alternative Theory of Information Diffusion

It is also possible to conceive of information diffusion as a communication process based on learning principles developed by Hull (1943) and formalized as reinforcement theory by Hovland, Janis and Kelly (1953). Using their theory, diffusion of information can be viewed in terms of persuasive communication. A persuasive message advocates something (in our case, a new idea) and is regarded as a compound stimulus which raises a question and suggests an answer. The question may be raised explicitly or implicitly, and the acceptance of the communication, which results in attitude change, is dependent on the incentives that are suggested by the communication. The incentives may be arguments or reasons supporting the new idea, or descriptions of overt reward and punishments. Acceptance, however, is contingent on two important variabels: attention, and comprehension. Before someone can be persuaded(accept message) he must attend to the communication (this is an argument for the use of interpersonal channels--which demand attention--in diffusion strategies); the individual must also comprehend the communication and assimilate it with other information in his possession. This process compares to Rogers' decision functions of knowledge, persuasion and decision about innovation information. Where Rogers' approach centers on the characteristics of the innovation, the social system, and the individual, the learning theory approach canters on the responses made by the individual to the communication about the new idea. In this there is a disadvantage; many of the process variables presumed are internal--intervening variables; these types of variables are empirically hard to point at. The advantage of the reinforcement theory approach is that the individual is the only unit of analysis: this makes for easy modeling.

Deeper discussion of this alternative conceptual approach to information diffusion is not pertinent for understanding the simulation. It was presented merely to be considered in terms of a possible "rival plausible hypothesis" for the effects generated by the simulation. It was also presented to provide the reader with another viewpoint regarding diffusion of information, and to caution him about the tendency to over-generalize on the basis of simplified models of a complex process, especially computer models constrained by time and money lacks.

Communication

Communication channels can be broken down into two types: mass media and interpersonal. Mass media channels can take the form of the electronic media like radio, television, and in some cases movies; and they can take the form of print media like newspapers, books and pamphlets. Interpersonal channels are, of course, people-to-people. In diffusion settings in less developed countries the people in the diffusion channels are generally professionally trained change agents (e.g., agricultural extension specialists) who have considerable communication skills. The functions of the two channels are different.

"Mass media channels are more effective in creating knowledge of innovations, while interpersonal channels are more effective in forming and changing attitudes toward the new idea," (Rogers, 1969a, p. 1-54). While this is the ideal case, we cannot always use mass media channels to create knowledge nor interpersonal channels to help form attitudes. This is because the use of the mass media imposes two demands on the system: literacy for print media; accessibility for electronic media (people must have radios to hear messages). In developing countries literacy is the main impediment to using print media, because in most diffusion settings people are illiterate. On the other hand, even if electronic media are available programs tend to be urban oriented in viewpoint and highly consummatory in purpose. Where used and relevant, though, the mass media provide an efficient and speedy way of transmitting messages of undistorted quality.

Because of the problems of literacy and information relevance, interpersonal channels are used in many diffusion settings.* These channels can be of two types: external and internal, depending on whether the person who communicates the message is a member of the village or a stranger--someone from the "outside." A combination of both external and internal orientation is usually preferred because individuals who carry the innovation messages should be well accepted by the

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*In some countries, like India, a combination of the two channels is used. This usage is known as the Radio Farm Forum. In this case farmers gather around a centrally located radio, hold discussions following an agricultural program, and send any questions to the radio station. These questions are answered in a subsequent program.

villagers but still have access to the outside world for their information soumces. Frequently, change agents are trained who have regular contact with urban information centers but who still live and are accepted by the village. When this is not the case, villagers with external contacts generally play the role of external information source (opinion leader). Some advantages to change agencies of using interpersonal channels are: ability to select receiver; immediate feedback between communicator and receiver. Having immediate feedback (information to the sender of the message about the receiver's reactions) about a message is advantageous because it allows the change agent to alter his message and be more persuasive. But, interpersonal communication has the problem of distortion: if someone is describing a new idea he may leave out certain details, etc., to reduce the effectiveness of the idea; it is also a slower means of communication than the mass media. This simulation models three interpersonal channels, two external channels and one local face-to-face channel.

Use of "Information"

We have said that the proposed computer model simulates the spread of knowledge of information about an innovation. Before continuing, it is important to discuss exactly how the concept of information is treated in the simulation.

Funkhouser (1968, p. 81) states, "The main difference between diffusion of innovation and the diffusion of information is that the former entails the decision of the diffusee to adopt the innovation or to reject it after the information of it has reached him." He explains that in a simulation of innovation diffusion additional factors would have to be added to account for processes like individual resistance and social system norms. Rogers (1969a) distinguishes between the idea component and object component of an innovation. The idea component (for example, the idea that a new fertilizer exists) is symbolically transmitted (communication) and manipulated (thinking), while the object component is actually transmitted (purchasing-obtaining) and manipulated (using). Utilizing the distinctions made by Funkhouser and Rogers, this simulation study deals only with the idea component of an innovation--information about the object--and makes no presumptions about eventual adoption of an innovation. However, "information" is still a difficult construct to define.

Morris (1968, p. 25) suggests that "information...is a meaningless construct unless specified in terms of its constituents--some set of symbols interacting with some receiver with information being produced as a result." For the purposes of this simulation then, we have incorporated this definition and designate "information" to mean the content of any message which conveys facts, ideas, or meanings that are new to the individual. In order for the information to be new to the person the message must contain familiar symbols (words that the individual understands--he must know what fertilizer is), and he must recognize that the information is new (that the fertilizer being communicated about is different than other fertilizers). Also, in this sense, information cannot exist if everyone knows about an idea. That is, information is a function of contrast: the more contrast between an individual's knowledge level of an idea and the knowledge level of the rest of the social system about that idea, the more information there

exists about it for that individual. So, what is information for one individual may not be information for someone else.

Thus, when we mention the diffusion of information in a social system, we are referring to the dissemination of messages which contain new ideational content for an individual (presumably for most individuals). Information "flows" in a social system in the form of messages communicated between persons. And, as will be discussed later, this simulation does not consider varying degrees of information about an idea: information is treated dichotomously--either a person possesses it or he does not. For an extensive discussion of the ways "information" is used in communication systems, see Morris (1968).

COMPUTER SIMULATION OF DIFFUSION

Computer simulation, according to Kiviat (1967, p. 53), is "the manipulation of a system's model to reproduce its operations as it moves through time." Pool, Ableson, and Popkin (1964, p. 188) emphasize time changes in their definition: "...simulation is any attempt to model a system in such fashion that the changes the main system goes through are imitated by the behavior of the model. A computer simulation is a programming and running of a computer such as to make symbols in the computer's memory change in ways that presumably correspond to the changes in the system being simulated."

It is important to realize, when considering a computer simulation, that the rules for modeling the changes described in the last definition are contained in the computer programming language: the language statements incorporate the assumptions of the model; these must be isomorphic with the assumptions of the broader theory for the model.

Often these assumptions are not explicit in the theory and must be contrived in order to create the simulation, but this is also one of the advantages of simulation: it forces explicit statement of theoretic assumptions. Simulations also use "parameters" which are fixed values that determine how the input to a simulation will be treated. There are at least two types of parameters in computer simulations: system definition parameters and computer processing parameters. The former parameters specify relationships between the variables in the social system being modeled, and also may be used to determine boundaries of the system, e.g., number of cliques. The latter parameters specify relationships between the computer and the simulation program (e.g., number of problems being run, number of time periods being simulated, etc.).

There is one additional important description of a diffusion computer simulation: it is sometimes a stochastic (also called Monte Carlo) simulation in that it uses variables which have no predetermined values, but rather are subject to random variation; the eventual value of a variable can be specified in terms of probabilities.

Two other terms are important in simulation: sensitivity checking and validation. Sensitivity checking is the procedure by which "...the investigator varies the values of certain parameters or relationships around the values initially built into the model. Then he examines how 'sensitive' or variable the model's results are to changes in these parameters or relationships" (Carroll and Farace, 1968, p. 73). If the model is sensitive to variations within a range of parameter settings then more accurate data are needed in order to estimate the "true" value of a parameter. If a model is insensitive to wide variations in certain parameter settings, there is little justification for including the parameter in the model. Sensitivity checking is one type of procedure in making a computer model more valid; validation is the overall confirming process which indicates whether the simulation is "...a reasonable and satisfactory representation of a system" (Kiviat, 1967, p. 54). In general, validation involves comparing simulated results with real world data for similarity. The greater the differences between data, the closer we need to examine (and possibly change) our modeled assumptions and the parameter settings. It is also possible that if the results are divergent, that the real world data are inaccurate (due to methods of collecting the data or analyzing it). The best way to insure against invalid data comparisons is to utilize results from more than one diffusion study in the validation process.

EVOLUTION OF THE SIMULATION MODEL: SINDI 1

SINDI 1 derives from the theories and models of Torsten Hägerstrand (1967), Georg Karlsson (1958), and Paul J. Deutschmann (1962a, 1962b, 1962c). Some of the concepts of Rogers (1969a, 1969b) about diffusion and communication are also used in the present model.

Hägerstrand's approach to diffusion is probabilistic and spatial. He presumes that information about innovations spreads most readily to individuals who are spatially close; these individuals interact more, a notion Hägerstrand calls the "neighborhood effect." The neighborhood effect is represented as a series of probabilities of possible contact between spatially related individuals. The probabilities comprise the "mean information field" of contact; and these probabilities are compared with random numbers generated in Hägerstrand's models by Monte Carlo methods.

Karlsson (1958) modified Hägerstrand's theory by considering social distance. Karlsson presumed that a person's willingness to communicate depended on the topic and the situation. The social constraints proposed by Karlsson are often labeled under source credibility in attitude research, and are akin to the concepts of homophily and heterophily promulgated by Rogers (1969a). These concepts state that communication is more likely between individuals of similar backgrounds (status, education, urbanization, etc.) and is less likely if the individuals are more dissimilar.

Deutschmann (1962b), building on the concepts of Hägerstrand and Karlsson, actually set forth the outline of the simulation model presented here (SINDI 1) in three mimeo papers written in Costa Rica in 1962. His model was based on a hypothetical Latin American village, and he primarily modeled its communication environment.

The technical structure, and to some extent the theoretical structure, of SINDI 1 has also evolved through several stages of programming. The prototype of the SINDI 1 model was programmed by Stanfield, Clark, Lin, and Rogers (1965) using artificial data for parameter settings and Deutschmann's verbal model in their computer program. They added the idea of determining variance from multiple runs around the average number of new knowers per time period. This idea has been used in all subsequent models. These researchers also utilized real world data to revise their parameters and produce a different series of simulation runs; the results of the runs are reported in Hanneman, Stanfield, Lin and Rogers (1968). Carroll later analyzed these runs, found several programming and logic errors in the model, and recommended the use of subprograms and certain theoretical changes included in the final model. Hanneman programmed the final version of SINDI 1, ran the sensitivity checking and other validation procedures, refined certain programmed assumptions and added a new pseudo-random number generator.

The Final Version of SINDI 1

SINDI 1 is an acronym for the Simulation of INformation DIffusion: a computer model which simulates the process of creating awareness or spreading information about a new idea--part of the first step in the innovation decison process. More specifically, SINDI 1 is a Monte Carlo computer model (one that uses random numbers to process the model) of information diffusion to peasant cliques in a small Colombian community. In the model, clique members, chosen randomly, are exposed to a combination of communicaton channels over a period of time. Through such exposure and additional local contacts an individual may become a "knower" of information about the new idea. If the new knower is designated a "teller" of information to others, he becomes a local source who can contact other village members.

SINDI 1 is programmed in USA Standard FORTRAN (United States of America Standards Institute, 1966) because the language is widely understood and available.

There are two objectives in this simulation. The first objective is to create a valid simulation of the information diffusion process, incorporating the four variables of opinion leadership, clique structure, channel structure, and amount of knowledge. The second objective is to examine closely the interaction of the modeled variables--through sensitivity checking--and to propose possible hypotheses for future reality testing by diffusion researchers. Simply stated, the objectives are to build a valid predictive tool which may contribute refinements to existing diffusion theory.

ORGANIZATION OF THIS REPORT

The remainder of this paper will discuss the theory and describe the SINDI 1 model. Specifically, Chapter II will discuss the theoretical basis of the model and the relevance of clique theory; Chapter III will describe the conceptual operation of SINDI 1; Chapter IV will describe the computer operation of the model applied to data gathered from a peasant village in Colombia; and Chapter V will discuss the results, critique the model, and make recommendations.

CHAPTER II

THEORETICAL BASIS FOR SINDI 1

As described in the previous chapter, diffusion research, with its profuse body of research, reports few instances of computer modeling. The exception is the work of quantitative geographer Torsten Hägerstrand (and his followers) of the Royal University of Lund, Sweden. This chapter reviews Hägerstrand's major contributions to diffusion simulation--the "neighborhood effect" and Monte Carlo simulation. The chapter then discusses how Karlsson simulates the diffusion process by including the notion of "social distance." Further discussions of the contributions of Deutschmann and others to SINDI 1 follows. The last section of the chapter presents a detailed rationale for including the concepts of clique structure and opinion leadership in the SINDI 1 model.

SIMULATION MODELS OF DIFFUSION

Hägerstrand's Models

The relevance of Hägerstrand's work to simulation of information diffusion is well documented in Stanfield, Lin, and Rogers (1965) and in Brown and Moore (1968). Readers interested in a deeper analysis and critique of the Hägerstrand theory should consult Brown, 1965, and 1966.

Hägerstrand (1967, p. 1) introduces his first chapter with the heading: "The systematic study of the distributional changes of cultural elements." He states that his objective is to deal with the diffusion of innovations as a spatial process. To him, diffusion of innovations is "the origin and dissemination of cultural novelties," a somewhat more restricted definition than used by the communication-sociological diffusionists. His approach is also geographic, in that distance, direction and spatial variation are of importance in his theory. Hägerstrand labels his approach the study of spatial diffusion rather than geographical diffusion because he is not only studying locational relationships between "vertical man and the earth's surface," but also between "horizontal man and man's relations." Another distinction he makes is between the relative and absolute physical and social distributions of a phenomenon: an absolute physical distribution is represented on a map, for example, by depicting every field occupied by a certain crop; this could also be a relative distribution if it showed the acreage under cultivation of that crop relative to the total acreage in a specific area. Social distributions are the representations of farmers who do and do not cultivate a crop--either represented on an absolute or relative basis. Social distributions, while not as accurate maps as physical distributions, are used by Hägerstrand in the form of social group distributions: the distributions of cultural phenomena among social groups regardless of spatial attributes. These social groups are mapped according to characteristics such as age, size of farm, etc. Ultimately, it is possible to superimpose "maps" of the physical and social distributions for comparison.

Hägerstrand (1967) has created three models utilizing the simulation ideas eventually found in SINDI 1. In Model I he defines the two main ideas for which he is well known in the diffusion field: information mediated via the neighborhood effect; and Monte Carlo predictions of information diffusion. Brown and Moore (1968) list these ideas as

Hägerstrand's two important conceptual contributions to the diffusion of innovations.

Hägerstrand (1967, p. 138) begins his discussion of information transfer by stating that the basic idea underlying the distribution of information of a new phenomenon is: "the distribution of information is synonomous with distribution of informed persons; the cultural element in question cannot be found where information does not exist; and the existence of information about an innovation does not in itself guarantee acceptance." (Acceptance being the second step in the reinforcement theory paradigm, presented earlier.) But Brown and Moore (1968, p. 6) restate Hägerstrand's basic tenet as being "that adoption of an innovation is primarily the outcome of a learning process." In looking at the spatial distribution of a certain innovation, Hägerstrand further assumes, as have subsequent computer modelers, that an informed population can only be divided dichotomously: informed and not informed. Also, acceptances by individuals occur independently of one another and in random order.

However, although acceptance of the information occurs randomly, and more and more acceptance "outposts" arise, the center of the distribution becomes more concentrated (p. 159) around the first possessors of information. In other words, there exists spatial continuity; the effect is what Hägerstrand call the "neighborhood" or proximity effect. But a point that many subsequent scholars have missed in expanding on Hägerstrand's notions: "the neighborhood effect is not a logical phenomenon unless we turn our attention away from public information (mass media), and accept the idea that private information (interpersonal)--especially face-to-face conversation--is the most important driving force behind the innovation diffusions under study here" (Hägerstrand, 1967, p. 164). This idea is similar to that described in Chapter I. Also, the importance of interpersonal channels in information diffusion about innovations is well documented (see Rogers, 1969a; and Katz and Lazarsfeld, 1955).

The neighboorhood effect is influenced by the concept mean information field. The mean information field consists of the private and public information fields. If we imagine a randomly scattered set of points (people), the communication pattern of one of those points to other points around it over time may be construed as an information field; it is either public or private depending upon the mode of message transmission. Hägerstrand includes only private information fields in his models, assuming some information has already disseminated via the public field. The mean information field is operationalized through a matrix of probabilities which indicates the probability of an individual in any cell being contacted by an individual in the central cell (the "teller"). This matrix expresses the idea that frequency of contact decreases with increasing distance.

The process of distribution is not as simple as we are lead to believe from Hägerstrand's first model, though. In another model, he introduces the resistance concept--that is, the individual's resistance to adopting an innovation.* The gist of the concept is that through repeated contacts with others, and other forms of obtaining information, the individual builds an information sum--when the sum reaches a certain point he

*This concept is programmed in SINDI 2, but not included in SINDI 1.

adopts--when the information sum is low the resistance is still in effect.

The second important conceptual contribution by Hägerstrand is his use of Monte Carlo simulation to create an operational model of diffusion. The rules of spatial relations are stochastically applied in Hägerstrand's models, yet there are certain constraints in the models--although randomly determined--which act deterministically, i.e., in a predetermined manner. For instance, Hägerstrand (1967, p. 267), randomly combines resistance levels with individual numbers according to a predetermined distribution of resistance levels within a cell of the mean information field. Note the similarity of this concept of deterministic decisions in a stochastic model to that of the information transfer probability notion in the next chapter.

There are some qualifications about such random methods which must be mentioned, however. It is generally accepted that even though the combined effects of human behavior may appear random to others (for instance, digit dialing appears random to a far-away monitoring telephone engineer), they are not random for the individual (the person knows the number). As Alan Perd says in the postscript to Hägerstrand's (1967, p. 308) book:

> Thus, when the rules of the game (the mean information field, the normal distribution curve of psychological resistance, or some other odds-setting device) are established for a Monte Carlo simulation model of the Hägerstrand type, a concession is made to the tendency of human geographic distributions to be more dispersed, clustered, or regular than random, and when cell assignments are made by drawing from a table of random numbers, a similar concession is made to the random aspects of aggregate decision-making and, by extension, the random component in virtually all human patterns.

It is also interesting to note that in much of Hägerstrand's work he assumes that information is always forwarded from knower to nonknower or to another knower at some time interval; contrast this with the notion of opinion leadership implemented in SINDI 1 and derived from the communicaton-sociological diffusion researchers. Brown and Moore (1968) have summarized the stochastically determined constraints used by Hägerstrand, which they feel are representative of all of his conceptual models: (1) the frequencies of the population which fall within a uniform grid; (2) the locations of adopters at time zero; (3) the probabilities of where a potential receiver falls in a resistance category; (4) the probabilities that two individuals at a certain distance apart will communicate;

This procedure of contact (utilizing the private information field) is basically as follows. A random number is generated, and falls somewhere within the matrix of the mean information field according to a predetermine (uniform) distribution. The mean information field is placed over a similarly gridded map and the location of the new knower-adopter marked. This effect is mediated, however, by the individual's resistance level--the higher the level the more information "hits" required.

Karlsson's Model

Karlsson (1958) wrote a rigorous book summarizing much diffusion and communication research. Based on his synthesis and a discussion of Hägerstrand and much interpersonal communication research (for example, he has extensively integrated concepts from Hovland, Janis and Kelly (1953)--concepts like source credibility, one-sided versus two-sided messages, etc.) he proposes a "model for pure interpersonal communication." Karlsson states that in his model the probability of some individual with social distance s and geographical distance g from the communicator receiving certain information is denoted by p_{gs}. Karlsson uses the quadratic cell concept (the mean information field of Hägerstrand) and so p_{gs} is also influenced by the number of individuals in the cell. The concept of social distance, however, he derives from communication research. (See Karlsson, 1958, pp. 33-45 for a discussion of the factors comprising the notion of social distance.) His concept of social distance includes such communication factors as perception and the selectivity processes, reference groups, message characteristics, and source credibility determinants. He also considers messages being perceived as rumor, listing consequent effects derived from research on rumor communication: assimilation, sharpening and leveling. It is also important to note that unlike SINDI 1, Karlsson limits his knowers to communication with one person per unit of time; after having told three persons, knowers become inactive. Karlsson also neglects to describe the idea of opinion leadership *per se*.

Although other diffusion simulators (Stanfield, Lin, Rogers, 1965, p. 21-22) give Karlsson exclusive credit for the notion of social distance, Brown (1966, p. 11) disagrees; in stating that the neighborhood effect could be a communication barrier in terms of distance, he says:

> ...since a terrestrial barrier does not differ functionally from a social barrier such as social class, it is not unreasonable to consider social barriers as a part of Hägerstrand's theory, terrestrial barriers having been emphasized only because Hägerstrand is working with diffusion through a sizable geographic space in which the

> social groups are relatively homogeneous (social barriers, therefore, having little effect upon a real differentiation of the patterns of diffusion).

Hanneman (1968) has incorporated the notion of social distance somewhat differently in a proposed simulation (programmable in IPL-V, a list processing language). This model uses an empirically derived mean status value and compares a simulated individual's status value with the mean. If the individual's generated status is much higher or much lower than the system mean, his attitude-toward-innovativeness score is weighted either positively or negatively. This score is also influenced by the individual's communication behavior, his role in the community, and by the system norms. Together these variables have the same effect as Karlsson's "social distance," but are manipulated in more precise terms.

Deutschmann's Model

The structure of SINDI 1 is directly attributable to the outline presented by Deutschmann (1962b). Deutschmann utilized the social distance concept formulated by Karlsson, but dropped the reliance on spatial variables. Rather than using Hägerstrand's social information networks, he divides the village into small social subgroups (called groups or cliques by different authors). This division is a good approximation by Deutschmann of a social system because it takes into account the distinction between communities and community loyalties which Hägerstrand neglects. He includes the notions of selective exposure and perception: the tendencies of individuals to expose themselves to information they want to learn; and the idea that individuals perceive information in ways consonant with previous experience. The tendency of selective exposure can also be thought of as a tendency to be oriented to certain channels more than others. Deutschmann includes three types of communication orientations: orientation to local face-to-face sources; and orientation to mass or impersonal sources. Deutschmann's model, unlike those of Hägerstrand or Karlsson, starts at the point of no information being possessed by any person. On the other hand, as do Hägerstrand and Karlsson, he perceives information to be dichotomous--a person is either a knower or a nonknower.

In addition to the selectivity processes just discussed, Deutschmann makes four other assumptions: (1) any message will inform the receiver, if it is delivered--this assumption is akin to one included in the early Hägerstrand models and in Karlsson; (2) any external message will touch off face-to-face messages--that is, messages from the mass media touch off communications between individuals; (3) face-to-face local messages flow more frequently within groups than between groups; (4) there is a small group of individuals which are called "tellers" (opinion leaders) within the community with a high probability of encoding information messages to others after they have received it; all others have a low probability of passing information. Note that this latter assumption differs markedly from those of his predecessors--who assume that all individuals when they become knowers have equal chances of contacting other nonknowers on a random-with replacement basis.

Deutschmann operates his information transfer by matching a message matrix to an audience matrix: that is, matching the channel orientation of a number of receivers to the channels through which an equal number of messages are sent and testing for similarity. Deutschmann states that p will equal one if the channel matches the individual's channel orientation, and in all other cases, p equals zero. Deutschmann also limits his tellers to four contacts apiece, a similar type of constraint formulated by Karlsson.

What is important to recognize in the above model, is the gradual transition it represents from the spatial to the social simulation approach. Hägerstrand was almost exclusively spatial (only because his receivers were in very homogeneous networks, if we are to accept Brown's contention); Karlsson also depended on spatial characteristics for information transmission but this was coupled with an equal emphasis on social characteristics; finally, Deutschmann neglects spatial variables almost entirely--except in the assumption that message transmission is more probable within cliques than without. Even though his cliques are homogeneous in terms of social distance (homophilous in Rogers', 1969a, terms), and their physical distance may be small, spatial relationships have little bearing on the transmission between clique members.

Deutschmann never programmed his model on a computer, but he ran the simulation by "hand" to approximate the effects. However, Stanfield, Clark, Lin, and Rogers (1965) built a model using Deutschmann's ideas. They state (p. 22) their simulation is designed to overcome two shortcomings in past spatial diffusion simulation:

> (1) An over-emphasis upon spatial variables and lack of full consideration of social structural and social psychological variables in diffusion processes.
>
> (2) The lack of emphasis in diffusion simulation on peasants in developing nations...

Their operationalization of the Deutschmann simulation model was the forerunner to the general SINDI 1 model.

CLIQUE STRUCTURE AND OPINION LEADERS

In the course of the theoretical development on which SINDI 1 is contingent, the simulation focus shifted from allowing all knowers a probability of one in contacting nonknowers, to a dichotomization of knowers into one group of tellers* (opinion leaders) with a high (p = 1.) probability, and another group with a low (p = .0) probability of communicating to nonknowers. Notice that along with this difference in possible teller contacts, there is a change in the modeled composition of groups. Hägerstrand uses the idea of a hierarchy of social networks. The networks operate with different members on different information field levels: person A makes certain contacts in his local information field, others in his regional information field, and still others in his national information field. Across these fields there may be one individual contacted by A in all three. This mutual contact makes the individual a frequently chosen source. While this situation is explained by Hägerstrand (1967, p. 239) it is not applied in any of his models. This point gets at the basic idea of opinion leadership.

Karlsson lumps all of his social system members into one large group and then implicitly subgroups them on the basis of their social

*Although the term "tellers" is used frequently in this study, strictly speaking individuals are not tellers until they themselves have become knowers of the innovation information.

distance, s and geographical distance, g from the communicator--in cells much like those used by Hägerstrand. Deutschmann, however, defines cliques on the basis of norm similarity and geographical proximity. Stanfield, Clark, Lin, and Rogers (1965) utilize this clique notion, and divide their simulated village into two cliques and one group of isolates--apparently only on the basis of geographical proximity. SINDI 1 defines cliques according to commonality of sociometric choices regarding communication about agricultural information.

Theoretical Justification

What is the theoretical justification for dividing the village into cliques, and ascribing a dichotomous communication function to its members? Deutschmann (1962, p. 2) states that "the introduction of this assumption is based upon research by the writer." However, to analyze this further, we must analyze two different but related lines of thought: (1) can we justify using clique divisions in analyses of diffusion patterns; and, (2) are there some system members who are really supraclique--who communicate with high probability out of the clique structures, as is assumed by Deutschmann?

Social-Psychological Basis of Clique Structure

Social psychologists like Newcomb, Turner and Converse (1965) talk in terms of interaction groups when discussing the structure of cliques. To them an interaction group consists of persons bound together on some basis, who have face-to-face interaction with one another over a continued period of time. Here, the basic core of larger groups is the mutually attractive dyad: an interaction relationship of two individuals who have positive attitudes towards each other. Dyads can form into larger groups known as triads, and "as the size of interaction groups increases, it becomes more and more likely that they will become differentiated into two or more subgroups" (Newcomb, et al., 1965, p. 309). Isolates are those individuals who have no stable relationships at all, even in dyads, and thus have no clique membership. To the social psychologists, a population is described in terms of the number of positively related cliques (in which members are attitudinally positive towards one another), the type of connections between different cliques, and the number of isolated individuals (isolates) found in that population. (Sociologists call the connections between cliques liaisons or liaison persons--indicating that they interconnect "...two or more subgroups in such a way that...removal from the communication structure would separate the two subgroups..." Yadav, 1967, p. 81.)

Because of work by Festinger, Schachter, and Back (1950) and the research in small groups by Homans (1950) social psychologists often cite the conclusion that attraction among individuals is often based on association--that is, the higher the attraction among two or more persons, the more frequently they interact, which in turn leads to greater attraction. In addition to an attraction bond, groups can also be analyzed in terms of similarity of members' attitudes, and in terms of personality characteristics. However, there is a more useful approach. It involves structuring cliques in terms of role relationships that exist between any two individuals who occupy certain positions in the system. This relationship can be differentiated in terms of power and authority (the family, for instance); knowledge and skill; and social status.

Newcomb, et al., (1965) reconciles the different ways social psychologists look at small groups in a statement that relates to both spatial and social diffusion:

> All groups have structures that may be described in terms of more than one dimension. It can always be said, for example, that every member of an interaction group has both a status relationship with every other member...and also a relationship of communication accessibility. Thus, any interaction group has a status structure, a communication structure, an attraction structure, and doubtless many others. (p. 346)

Communication accessibility refers to the amount of communications oriented toward particular individuals in the group. Distance in terms of accessibility may be determined by the physical nearness or remoteness of position holders, or by role prescriptions according to which specified position holders are required or forbidden to communicate freely with each other. The distances refer to degrees of difficulty or delay in getting messages transmitted; they may in fact be regarded as barriers to direct communication. Thus, the distance between any two persons has direct effects on their behavioral relationship (Newcomb, et al., 1965, p. 344).

Sociological Approach to Clique Structure

Sociologists, such as Chinoy (1961), see the small group as the fundamental form of social organization. To Chinoy, social groups--a number of persons whose relationships are based upon a set of interrelated roles and statuses--are populated in one form or another by all of society. (Note the similarity of this definition to the more microscopic definition of the social psychologists.) One type of social group--and the one pertinent here--is one characterized by close and intimate relations, not necessarily goal oriented, and held together by the intrinsic value of the relations: the primary group. A primary group might be the family, friends, part of the neighborhood, etc. From findings from the Hawthorne studies at Western Electric, and by William Whyte, Chinoy (1961, p. 103) concludes "The primary group, then mediates, in a sense between the individual and the society in which he lives." On one level, the primary group serves the function of providing reassurance, psychological, and emotional support for its members. On a higher level, by operating around positive or negative societal norms and values, it serves the purpose of unifying the persons who belong by providing them with reference for their behavior. In a sense, the primary group provides its members with a smaller society within the larger, complex society.

What is significant here is that Chinoy (1961, p. 100) posits the same statement that the social psychologists do and which is sometimes also found in the diffusion literature: "numbers, frequency of interaction, and shared vluaes, then constitute conditions that make possible or inhibit the formation of primary groups, but the key factor would appear to be the functions they serve their members." To elaborate on this, we turn to a study by Lionberger and Coughenour (1957) which discusses extensively the function of social cliques in Missouri.

These researchers say cliques are non-kindred groups which satisfy many of the socio-psychological needs which might once have been satisfied by the neighborhood. Neighborhoods consist of individuals bound together by proximity and perhaps some commonality of interest; cliques consist of individuals bound together on the basis of a common characteristic without regard to physical nearness. To Lionberger and Coughenour, neighborhoods are relatively longer lasting phenomena than cliques; cliques also tend to be somewhat heterogeneous in regards to the mean prestige of their membership. They see the clique as a phenomenon accompanying the change from traditional rural society to a modern society that has become more spatially mobile and more selective with respect to intimate association. They found that information seeking on the part of lower prestige members to higher prestige members, or to those contacted most frequently, was best facilitated when the influencing member was a member of the same clique, and most inhibited when the influential (opinion leader) was not a member of the clique. Lionberger and Coughenour hypothesize that locality types of social structure (neighborhoods) predominate where "particularistic and ascriptive" values are found, while social cliques flourish where "universalistic and achievement" values predominate. Related to that hypothesis, they found that clique membership was more prevalent among farmers living outside, than among those living inside, neighborhoods. They also found (with close to statistical significance) that information-seeking-relationships with regular contacts (an individual contacted regularly, not necessarily a friend--e.g., a storekeeper) or with friends were unrelated to membership in either a neighborhood or a clique; however, information seeking relationships with local influentials is based upon a different type of norm than the same behavior with friends or regular acquaintances. Specifically, the former is probably based upon rational, instrumental norms relating to agricultural technology and the latter type of behavior is based on nonrational, traditional norms. A possible implication of this last conclusion, relevant here, is that opinion leaders and cliques are more modern oriented phenomena--possibly not relevant to more traditional peasant societies. Unfortunately, their findings only can be generalized to Missouri and perhaps the United States.

Hubbell (1965) developed a method for determining clique structure based on the strength of the dyadic relationship in the social system. He interprets interpersonal communication as being equivalent to influence; influence felt in one part of the system is transmitted elsewhere (as relayed outputs and inputs), but most strongly to cliquemates. Hubbell, unlike the two researchers above, allows for an individual to be part of a clique on the basis of a few strong bonds, even if the bonds are fewer in number than many weak ones. In his model, then, the degree of influence determines the cohesiveness of the clique, not just the similarity of incoming and outgoing choices. Since the cliques are determined by strength relationships, and these structural linkages are regarded as input-output channels of influence transmission as above, intraclique members will be influenced more strongly by one another than by outsiders. As Hubbell points out, the model thus has functional significance (in much the same way as the functional significance of the sociologist's primary group), because the influence flows affect the performance level or status of each person in the group.

Loomis (1960b,p. 481) states, on the basis of his research in the pseudonymous Southtown, that "...in most rural areas where there is little opportunity to move up and down the social ladder, most groups are family friendship groups." Note this finding is not congruent with the findings of Lionberger and Coughenour (1957). Loomis distinguishes between the prestige or power system, and the communication or information system in the community which tie the different groups together. On the basis of his research he concludes that everyone (all of the family kinship groups) is part of the communication system, but only few are members of the prestige system. Those who are members of the prestige system, are members of existing cliques who have contact with other cliques, or who are frequently contacted by other clique members. He considers the prestigious persons to be essential in the communication process--unlike Hubbell. Later research by Loomis (1960a) in a Spanish speaking village in New Mexico found cliques based only on extensive kinship patterns. "These family friendship groupings with their central families with grandchildren constitute the so called 'larger family,' common in Latin American and other familistic cultures," (Loomis, 1960a, p. 490). This latter statement of course has salience for this simulation because SINDI 1 was applied to a communication environment in Latin America.

A communication-sociological diffusion researcher like Rogers has not, to date, discussed formation of cliques in any explicit way. However, in his recent book (Rogers, 1969a) he uses the concepts of homophily and heterophily to refer to tendencies of interacting individuals to be different or similar in regards to attributes, beliefs, values, education, status, etc. He states that most human communication takes place between individuals who are homophilous, thus leading to more effective communication. It may be possible to infer that he implicitly recognizes the importance of cliques in diffusion theory; on this level, cliques exist because of individuals, who on the basis of similar characteristics tend to have a higher probability of interacting. This notion is similar to the one of social networks proposed by Hägerstrand and explained earlier.

However, there is a problem inferring this meaning from Rogers' theory. For, in his (1969b) description of the subculture of peasants, he cites that a characteristic of peasants is mutual distrust in interpersonal relations. He finds peasant communities characterized by a mentality of mutual distrust, suspiciousness, and evasiveness. The peasant also lacks trust and cooperation with and from his fellow man and tends to be highly individualistic. This appears to contradict the existence of cliques. But, mutual distrust of other peasants means greater dependence on the immediate family. Rogers reports the observations of other researchers who have found that the peasant views his family and their cooperation as being essential to him, a type of cooperative insurance against aggression and exploitation, and without which the individual stands isolated. This corroborates the findings of Loomis (1960a, 1960b). See also Banfield (1958).

Opinion Leadership

Before we draw conclusions about the relevance of clique membership we must still discuss opinion leadership. Rogers (1969a, 1-48) defines opinion leadership as "the ability fo informally influence individuals' attitudes or behavior in a desired way with relative frequency." And, opinion leadership "is earned and maintained by the individual's technical competence, social accessibility, and conformity to the system's norms." Rogers points out that opinion leadership is a process which stands in relation to another person--it is not an isolated attribute. Also, opinion leaders may be active or passive--they may be sought by, or they may seek followers. Rogers (1962, p. 212) has also stated that opinion leadership is not to be considered a dichotomous variable: either you possess it or you don't. Rather, individuals may possess varying degrees of it; and may also possess it only for certain topics. Acceptance of this assumption that opinion leadership is a matter of degree, was not acknowledged by Deutschmann (1962b, p. 2) in his model (the fifth assumption) nor in any subsequent programs of the SINDI 1 model since that time. This neglect is one of its major drawbacks. SINDI 1 also assumes that opinion leaders are always active--they do the contacting. But recent research (Troldahl and Van Dam, 1965) disclosed that opinion leaders are also passive, and in most instances there is mutual opinion sharing occurring between opinion leader and asker.

Let us draw some conclusions now regarding the two questions posed at the beginning of this section: Is there theoretical justification for clique division and the concept of opinion leadership?

Conclusions

It is important to realize that in much social science research dealing with aggregate data it is possible to form groups based on descriptive statistics of some characteristic alone. For instance, it is possible, as Deutschmann does, to deduce that all members of a certain race are a clique in the same manner as those with a commonality of attitude about say, cars, can be considered to form a clique. Thus, on the aggregate level, persons may be grouped together on the basis of similar social attributes and logical relations, yet it would be fallacious to imagine these persons as interacting together (although it is possible that they do). We use "clique" to mean a group of individuals bound together on the basis of shared interests, attitudes or ideologies. Clique membership may have little relation to proximity or demographic characteristics.

Based on the exposition developed here, however, it is possible to accept the notion of clique structures in social systems as being relevant to the SINDI 1 model. The exact nature of a clique may differ with the society it's found in, but it can still be called a clique. In a modern society with much social stratification and mobility, true cliques exist on the basis of shared interests, attitudes, or some other attribute--without reference to spatial proximity. In more traditional societies, especially in countries with peasants--and in the peasant village being simulated--little stratification exists, there is little diversity of interest and the cliques that do exist are probably based on family ties. Furthermore, the following statements can be drawn from the above:

(1) Intraclique contact is predominant over interclique contact; relating this to information diffusion we can generalize that information diffusion occurs faster within cliques among specific dyads in it and is mediated to other dyads in the clique by opinion leaders. Theoretically, therefore, a new knower of information should be allowed to make contacts within his clique after receiving information.

(2) Cliques very often take the form of extended family-friendship groups in peasant systems. If houses are not centrally located in a village, but on farms, spatial proximity may have some importance.

(3) Liaison persons are those individuals who tie two subgroups together; they can be considered opinion leaders with low degrees of opinion leadership (or perhaps interclique "gatekeepers") depending on the amount of other cliques the person has liaison with.

(4) Opinion leaders are always members of a clique--at least in the sense that they communicate information and are sought by other dyads in the same clique.

(5) There is a conceptual difference in being contacted by an opinion leader (teller) and seeking out an opinion leader.

(6) Opinion leaders have more contact within their clique than out.

Discussing the influences of groups in the communication system of society, Katz and Lazarsfeld (1955, p. 130) point out that groups have two effects on their members: group norms and patterned channels both within and without the group. The former factor is important in conclusion five, above; intraclique communication will always be more successful because the group's norms reinforce the attitudes of the group. Also, the crucial individuals in the patterned (regular) channels are the opinion leaders who determine whether the information will be circulated in the clique (as described in conclusion one, above), whether it will be favorably received (he legitimizes the information), and whether information from within will be transmitted outside of the group (the opinion leader acts either as a gatekeeper by filtering information from seekers, or by not acting as liaison in sending the information to other cliques).

CHAPTER III

GENERAL DESCRIPTION OF THE SIMULATION MODEL

Based on the concepts and theory presented in Chapter II, we are now ready to describe the general SINDI 1 model. We begin this chapter by first describing the model's assumptions. Then, the following section contains a discussion of the parameters in the model, and the last section will describe the conceptual operation of the model.

ASSUMPTIONS IN SINDI 1

The assumptions listed below are related to the assumptions of Deutschmann (1962b) stated in the previous chapter (pp. 25-28).

Assumption 1: message reception is selective. This assumption is based on research disclosing selective information seeking by individuals. This notion predicts that a person will orient himself more to certain communication channels than others, and will not accept every message he attends to. This assumption is operationalized in the model by the parameter CHANOR, which allows presetting of individuals in the audience matrix to certain channels. It is also operationalized by means of the external message matrix probabilities (also called the information transfer probabilities*) which are compared with random decimal fractions between zero and one in the simulation of information transmission. This procedure says, in effect, that people have selective probabilities of receiving information from a particular channel, and

*The references to information transfer probabilities imply information transfer between dyads although often it is used in this study with reference to single individuals only.

for each message from that channel there is a selective probability that the message will be accepted by the individual.

Assumption 2: initial contacts between channel (external or local) and members of the modeled social system are randomly determined. By contacts we mean two people communicating (not necessarily about innovations). For example, an extension agent may stop by to see a farmer and only talk about the weather.

Assumption 3: the probability of information transfer from a channel-source in contact with a nonknower depends on the nature of the relationship. Even though only one type of probability is discussed in the study, that is, the information transfer probability based on contacts with external channels or local tellers, the probability is conceptually two probabilities. It is both an information "imparting" probability, i.e., given a contact with a channel, will the channel actually communicate a message about an innovation during the contact. For example, the greater the social distance between individuals as measured by clique membership the less the probability of imparting information. The transfer probability is also comprised of an information acceptance probability, i.e., given that a channel communicates information about an innovation, will the individual accept it?

Assumption 4: external messages will touch off local face-to-face communication if the person contacted (the new knower) is a teller. This assumption is related to the fact that in planned change, information about innovations always comes from external channels first, and then diffuses to tellers who communicate the information locally. The assumption is operationalized in the teller contact routine, where new knowers are checked to see if any are also tellers, and if so, then are allowed to contact nonknowers.

Assumption 5: only tellers are allowed intra- and interclique contacts, all other individuals are restricted from communicating to nonknowers. This is one of the most tenuous assumptions in the model, and based on the theory presented in the previous chapter, future models should allow all knowers to contact nonknowers. This assumption is operationalized by the teller contact routine.

Assumption 6: face-to-face local messages flow more frequently within cliques than between cliques. This is operationalized through the use of the local message matrix in the same manner as the message matrix described in assumption #2. As Deutschmann (1962b, p. 5) mentions, this is a modification of the selectivity assumptions, because regardless of a person's channel orientation he will be exposed to local teller contacts.

PARAMETER DESCRIPTION

Earlier we said that SINDI 1 uses two types of parameters: system definition parameters and computer processing parameters. The former parameters define the boundary conditions of the model or define the degree of relationships between variables in the modeled system. The processing parameters are fixed values which specify the constraints of certain operating rules for the computer (e.g., number of problems being simulated).

System Definition Parameters

1. Number of cliques and the amount of members in each. These are labeled NCLIQS and NMEMCQ(ICQ)--they are related such that for each value of NCLIQS there is an equivalent NMEMCQ(ICQ) value (in technical language, NMEMCQ(ICQ) is dimensioned by the clique number--1 through 5). They are read in at the beginning of INPUT and are used throughout the simulation in determining values of variables contingent on specific clique membership, e.g., information transfer probability. The number of clique members is totaled in INPUT to obtain at TOTIND, a parameter for the total number of individuals being simulated. This parameter is frequently used as a limiting value in various iterations.

2. Number of external message channels. This is labeled NXCHAN in SINDI 1; it is also defined in INPUT. The parameter controls the number of cycles through the external message contact routine. The program allows for up to five external channels.

3. The individual's channel orientation. It is defined (as CHANOR(IN))in INPUT from the data card matrix of channel orientation for each clique member. It is used in the EXTMES routine to check the individual's orientation with the channel being used.

4. Number of contacts allowed each external channel source. This is labeled NXCCON(ICH) and is related to the number of external channels. That is, for each external channel, there is an associate NXCCON(ICH) value. The NXCCON(ICH) parameter determines the "activity" of the external channels in contacting individuals. The total contacts allowed the two external channels per time period is equivalent to the sum of all the values of NXCCON(ICH).

5. The probability of a nonknower becoming a knower through contact with any external contact source: this is the dyad's information transfer probability based on the receiver's channel orientation and the particular channel he is in contact with. This is labeled PKWXCH(INCHNL,ICH) and is determined by the matrix location of the intersection of the individual's channel orientation with the contacting channel's number. It is used as a comparison with a randomly generated decimal in the EXTMES routine.

6. Number of tellers in the simulation. This is labeled NTELRS, and is determined from the total amount of individuals listed in the teller orientation matrix in the data. The data defining the parameters are arranged so that the first individuals read in are the tellers. This parameter controls contact cycling in the TELCON routine.

7. Number of contacts allowed a teller once he becomes a knower. This parameter, known as NTLCON is defined in input and determines the amount of contacts each of the NTELRS can make during a time period.

8. The probability of a clique member becoming a knower through contact with a teller from any clique. This is labeled PKWTLR(ICQ,ITELCQ) and is a dyad's information transfer probability based on clique membership of the receiver and the clique membership of the contacting teller. It is compared with a randomly generated decimal to determine acceptance of information through local word-of-mouth channels in the TELCON routine.

Processing Parameters

In addition to the above values, there are certain parameters which control the processing of the program; they are as follows.

1. Number of problems. This is labeled NPROBS and is read in from a data card in INPUT. It allows the program to be used with varying sets of data, simulating different situations, without the submission of new cards. Or, the same data may be run for a number of consecutive problems, with a variation in parameter settings for each problem in order to test the sensitivity of the parameters.

2. Number of runs. This is sometimes called number of iterations, and is labeled NRUNS. This parameter allows for replication of simulation without reinitializing the system definition parameters (which must be reinitialized for each problem). As has been suggested elsewhere (Stanfield, Lin, Rogers, 1967, p. 17):

   > An important feature of the SINDI 1 model is that multiple runs or iterations of the simulation are facilitated. If we regard a complete run of SINDI 1 from generation (time period) 1 to n as a random sampling of one diffusion process from the many possible diffusions of an innovation in the village, we certainly would wish for a number of such elements in our total sample so as to be able to estimate sampling error and the true parameters. SINDI 1 can easily replicate the complete simulation periods as many times as specified, so that a sampling distribution of diffusions is obtained and estimates about the true parameters are made.

3. Number of time periods. This is labeled NTIMPS in simulation; each time period unit is equivalent to one year of real-world time: the parameter is defined at the beginning of the INPUT routine (see Figure 1) from a value on a data

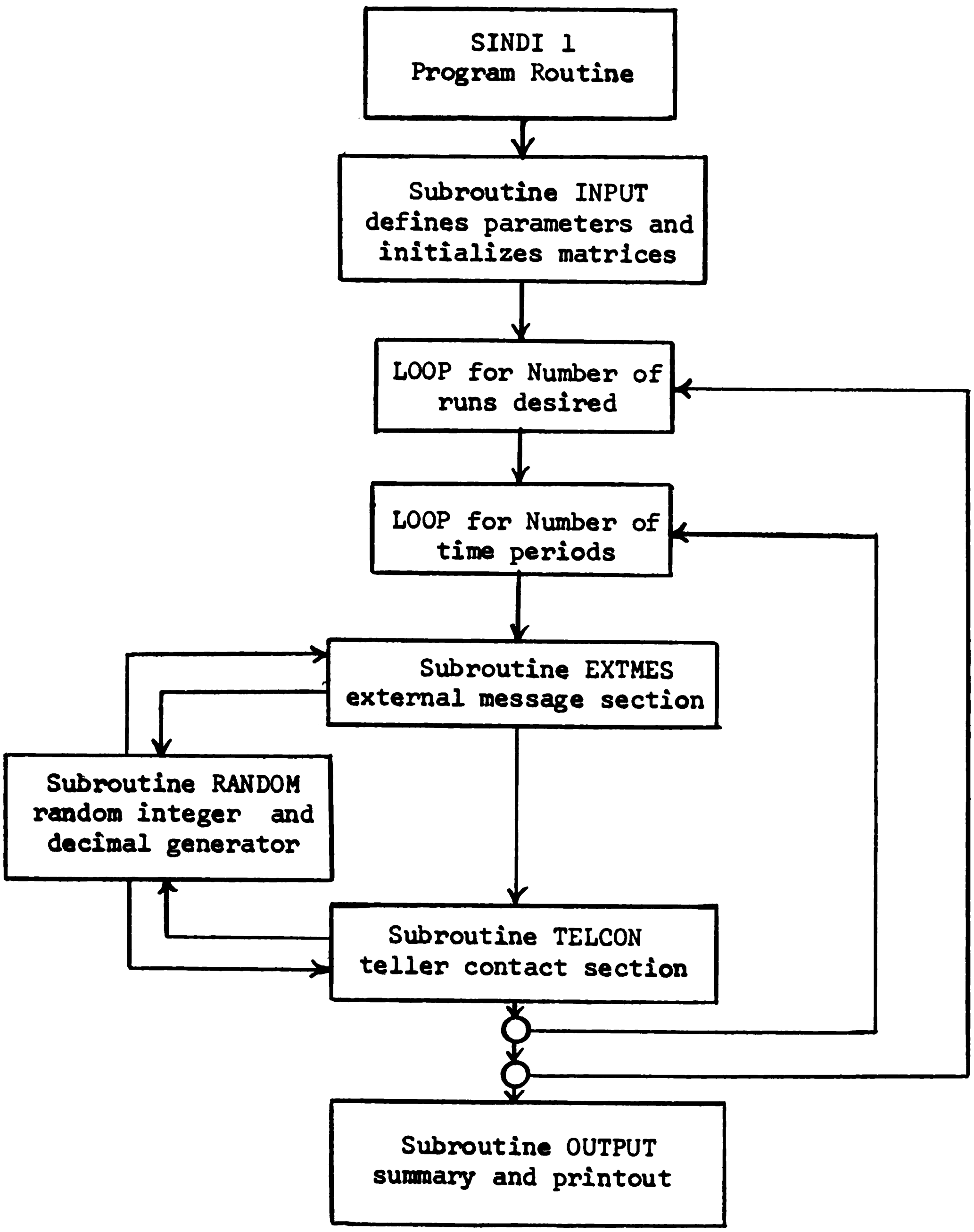


Figure 1. General Flowchart for SINDI 1

card. This parameter controls the number of iterations through the EXTMES and TELCON routines, i.e., the number of times the channels are allowed to make contacts.

4. Number of detailed printouts of the simulation. This is labeled NPRINT; is also determined in INPUT and is used throughout the simulation as a check value of the number of runs completed and printed, with the number of runs to do.

5. Choice of logical units. The user must specify the identification number of the logic unit he wishes to use for input, output, or punch, by specifying the numbers for LUNI, LUNO, and LUNP, respectively, in the program deck.

There are also various internal indexes and keys used as programming aids. Definition of them is found in the program listing, Appendix A.

STATE VARIABLES

If we imagine the system definition parameters as being input values to the simulation, we should then determine what they "operate" on to produce the output variables. The variables operated on may be thought of as state variables in that they take on different "states" (i.e., different values) during the course of the simulation run.

Individuals may then be thought of as having lists of attributes, or variables, depending on the way they are described. As an analogy we might imagine the parameters being the innate characteristics of a person, while the state values are values which a person learns during life and which constantly change and affect his behavior, depending on the experiences he encounters. State variables in the simulation are as follows (each of the variables below takes on a different value for each individual in the simulation):

1. CHNSOR(IN) is the individual's "memory" of the channel source which informed him (if it has). This can take on a value of 0, 1, or 2--depending on whether a local channel contacted him, or whether external channel 1 or 2 contacted him. It is primarily used as a memory trace for analysis of the output.

2. TLRKWR(IN) is a variable name which describes whether a new knower is also a teller; if he is, then he is activated one time period later as a contacting agent in the TELCON routine; if not he remains inactive. This variable is set to zero or one representing a "no" or "yes" that the teller is a knower.

3. KNOWER(IN) a variable which tells whether the individual is a knower yet; the setting of this variable tells the routines that if he has been informed, not to count him again as a new knower. This also takes on a value of zero or one.

4. TELSOR(IN) is the individual's memory of the teller who informed him (if he has). It is the actual individual identification number, and is primarily used as a memory trace in output.

(Note, SINDI 1 is set up to simulate up to 100 individuals. If the simulation exceeds this amount, the array dimensions must be changed.)

DESCRIPTION OF SINDI 1

The SINDI 1 program consists of an executive routine and five subroutines. (Refer to Figure 1, a flowchart of the general operation of the routines.) The main program routine handles monitoring tasks for the simulation. It executes the main DO loops (one for the problem cycle; one for the run cycle; one for the time period cycle) and calls the other subroutines. The first subroutine, INPUT, inputs parameters and initializes arrays for the beginning of a run and a particular time period. (One run ends after all the specified time periods have been completed.) This routine also prints parameter list headings in the output and handles other data input chores. The next routine, EXTMES, is the external message section. Here the theory about the external interpersonal channels is manifested: this routine simulates individual contacts by channel-sources leading to either message acceptance (the person becomes a knower) or non-acceptance (the person remains a nonknower). Subroutine TELCON is the teller contact section, which includes the theory of local face-to-face contacts between tellers and nonknowers. Subroutine OUTPUT controls most output functions for the simulation program. It can be keyed to print-out either detailed individual-by-individual contact traces, or statistical summary data, for each time period and for the entire simulation period (i.e., one run). Subroutine RANDOM is a random number generator which provides random integer numbers within a specified range, and associated random decimal numbers. The generator functions with or without replacement* and is also based on an extension of Lehmer's rule.

The program begins by calling subroutine INPUT. Input reads in data from the data cards to determine the number of problems, runs and time periods, and the composition of the cliques. It creates a matrix of the clique composition of the social system which includes the total number of individuals included in the simulation, their channel orientation, and whether or not they are tellers. This part of the model also arranges the information transfer probability matrix. The input parameters are printed out as an "Input Section" following the program listing to assure that all data are properly read in and ordered. Some of the statistical variables (e.g., mean) are also

*Sampling with replacement is sampling from a hypothetical population whereby everyone is replaced in the total in order that the next individual chosen has as equal a probability of being selected as all previous persons.

initialized in this section. When all of the data have been processed, the input section and the individual identification list (see Appendix A) printed out, control returns to the executive routine. Then the program enters the run DO loop, cycling through attribute list initialization, followed by entrance to the simulation time period DO loop. If the print setting (NPRINT) is at least 1, headings are printed out for the output section.

The executive routine next calls the EXTMES routine (see the flowchart in Figure 2). Here the simulation enters the external channel DO loop, cycling through the statements in the routine as many times as the NXCHAN (number of external channels) setting allows. The random number generator (Subroutine RANDOM) is called to supply as many random individual numbers as is dictated by the number of contacts for that channel (NXCCON). For each random individual generated (called RANIND) as associated random fraction in decimal form (RANDF) is also generated to compare with the listed information transfer probability. When the random generator is called, the arguments specify the type of desired sampling, the upper and lower limits of the random numbers (i.e., from one to the total number of individuals in the simulation), and the total number of random individual numbers desired. (While we could generate an amount of random numbers equivalent to the total amount of individuals in the simulation, this would be wasteful of space in the computer's core memory--therefore the generation is limited to the number of contacts allowed each time period.)

In the generator, a random integer is generated, the power of ten needed is calculated, and the number is truncated appropriately. After

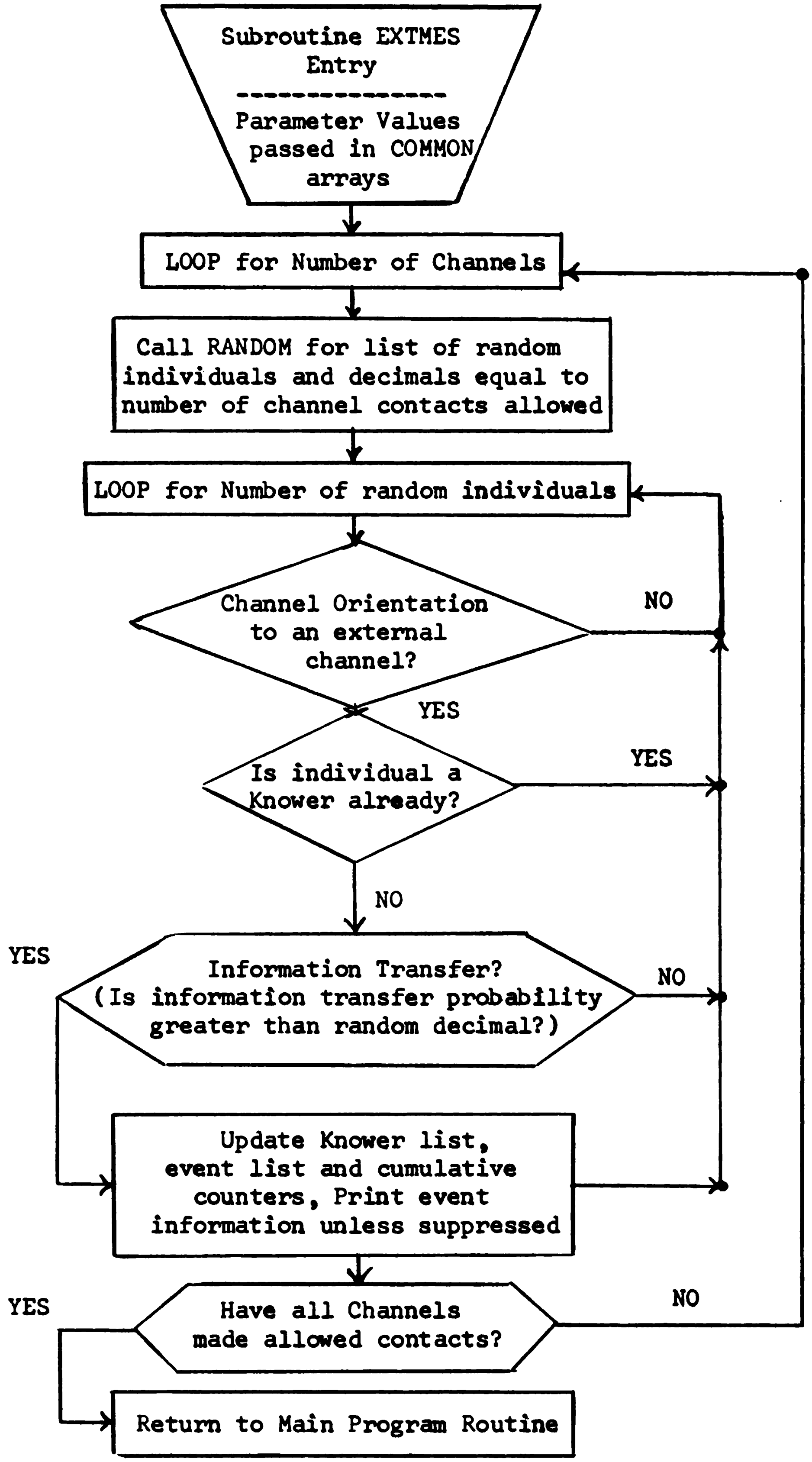


Figure 2. Flowchart of EXTMES Routine

truncation, the test is made for the replacement option; if no replacement is desired, the number is tested to see if it is within the desired range. Immediately after this procedure, another random integer is generated, converted to decimal and associated (in a matrix) with the integer generated prior to it.

Control returns to the external message section and the random individual is located on the identification list to determine his channel orientation, and if he is already a knower. A random decimal is compared with the information transfer probability to represent the process of the individual receiving information about the innovation from an external channel message contact. If the random decimal is less than his information transfer probability, then the individual becomes a knower; otherwise, he remains a nonknower.

If he does become a knower, the single event and cumulative event counters are incremented, and the knower tallies for each clique incremented. Also, the individual's attribute matrix is updated with the information that he is a knower and which channel contacted him. If the individual also happens to be a teller, the teller activation tally is incremented. To conclude the routine, the information just tallied is printed out (unless suppressed) for each individual in the output section. The external message section continues cycling until a channel has made all of its allowed contacts. Then, another channel is activated and the process is repeated for the number of contacts it is allowed. After all channels have made all of their message contacts, the TELCON subroutine is called.

The TELCON routine (see Figure 3) does not process a knower-teller until one time period after their activation. This routine first checks

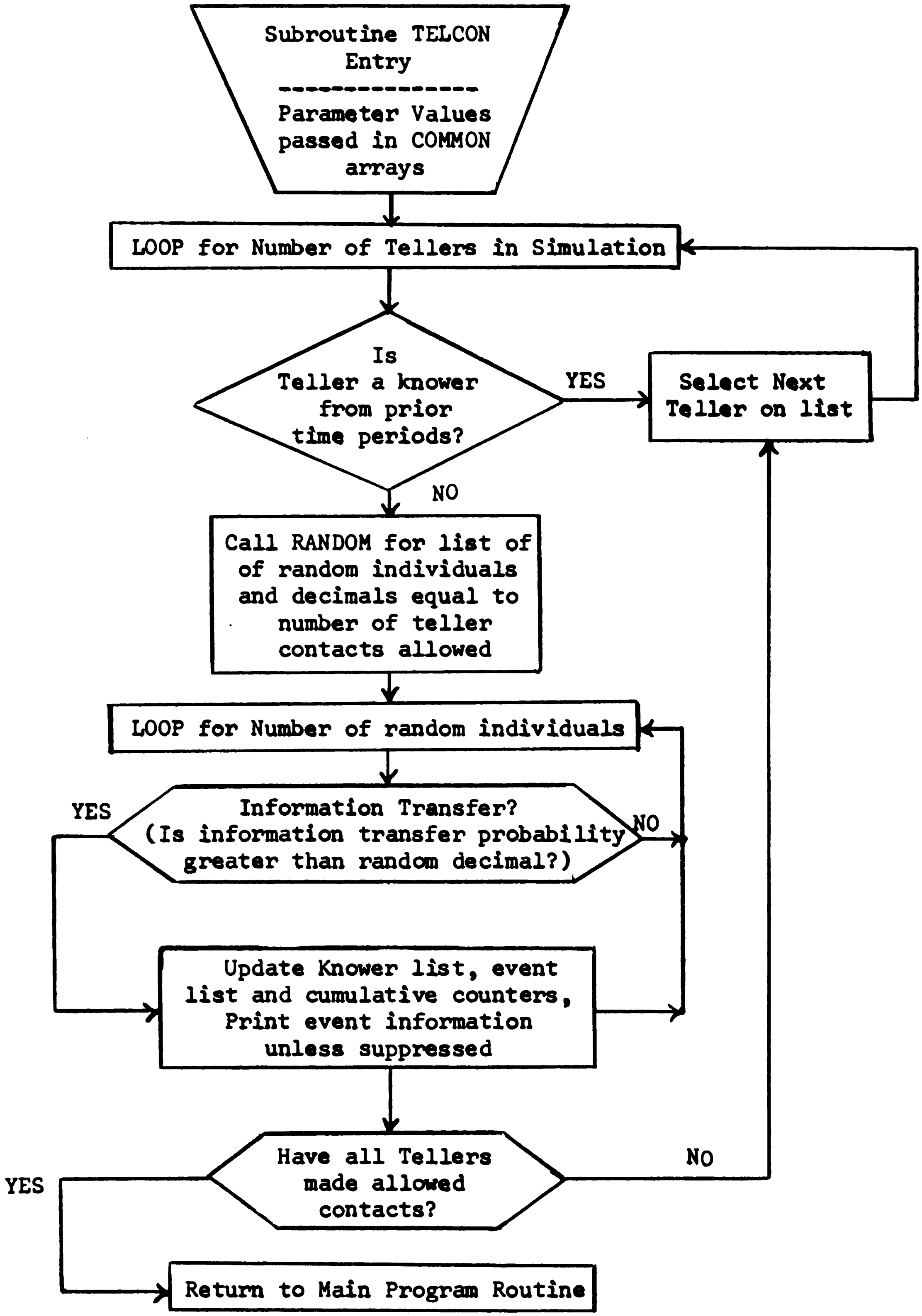


Figure 3. Flowchart of TELCON Routine

the list of potential tellers to see if any are knowers from previous time periods. If not, the routine returns control to the main routine, checks if any of the new knowers from the external channel contacts are also tellers, and sets the attribute matrices appropriately. The program then begins another time period.

But, let's presume we have at least one activated teller from a previous time period. The teller contact routine would then call for RANDOM to return a list of randomly chosen individuals which the teller will contact during the current time period. The number of individuals on this list is equal to the number of message contacts, NTLCON, allowed each teller during a time period. Each random individual is checked to see if he is a knower already--if he is, the teller has "wasted" one contact and goes on to the next individual. If the person is not a knower, the information transfer probability--based on his clique membership and the clique membership of the teller--is compared to the random decimal in the same manner as in the external channel routine. If the person becomes a knower, the attribute matrices and counters are changed. The routine runs down the list of random individuals until the contacts for that teller have been exhausted. When they are, a check is made to see if any tellers remain, and if so, the routine continues to cycle, repeating the procedure for each remaining teller and the number of contacts allowed during that time period. If no tellers remain control returns to the executive routine for updating of the teller-knower list. This process continues for the remaining number of runs and time periods. When all runs are completed, OUTPUT is called to print a summary of contacts made, and print descriptive statistics if desired. OUTPUT can also only summarize data after each run if the detailed summary is not wanted.

The entire program cycle continues until there are no more problems left, at which time the simulation exits.

OUTPUT VARIABLES

Output variables are produced by the simulation on the basis of the parameters' effects on the state variables described above. For each time period the simulation outputs five items of information.

1. The number of events during a time period. This variable is called NEVENT. It is the number of clique members who became knowers as a result of being informed by one of the three channels, i.e., each time someone becomes a knower a diffusion event occurs.

2. The number of cumulative events to date. This is labeled NCUMEV. It is important in determining the cumulative frequency curve of knowers over time.

3. The cumulative number of tellers activated during a time period. This is labeled NTELAC, and is only incremented when the teller is actually active in the simulation, not during the time period that he becomes a knower.

4. The number of new knowers in each clique this time period. This is labeled KNOTLY and is used for analysis purposes in the detailed output.

5. The number of total new knowers to this time. This variable is called KNOSUM and is also used for analysis purposes in the detailed output.

In addition to the output variables, the simulation is able to print detailed summaries for each time period: (a) which channel-source contacted which individual, and (b) whether information was accepted during the contact. The comparisons of the information transfer probability with a random decimal are also listed for each contact, unless this type of output data is intentionally suppressed.

CHAPTER IV

SPECIFIC RESULTS OF THE SIMULATION

Previous chapters have presented the theory from which SINDI 1 models, and have also discussed the assumptions and parameters used in the general model. This chapter describes the derivation of the data used in this simulation with SINDI 1 and the results from runs based on that data.

BACKGROUND DATA ON THE VILLAGE OF PUEBLO VIEJO

The validation data and the data used in determining parameter values in SINDI 1 are from Rogers' (1965) research in Pueblo Viejo, Colombia. Pueblo Viejo is a small peasant community located about 40 miles from the capital city, Bogota, in the foothills of the Andes mountains. The community is generally characterized by "...extremely small farms, operated by subsistence farmers of mixed Indian-Spanish stock with relatively low levels of education, serious poverty, and very limited economic opportunities" (Rogers, 1965, p. 616). The purpose of Rogers' study was to investigate antecedents and consequences to mass media exposure in five communities in central Colombia, among the Pueblo Viejo.

Despite some mass media usage in the community, there were no reported instances of learning information about agricultural innovations from the mass media, because the media lacked relevant agricultural content and were largely urban oriented and consummatory in purposes.

PARAMETER ESTIMATION

The values of many of the parameters used in the runs of SINDI 1 reported here were determined by Stanfield, Lin, and Rogers (1967). While some of parameters (e.g., channel orientation) have a theoretical basis for their values, the parameters for number of channel contacts and especially information transfer probabilities were arbitrarily determined.

The parameters below are presented in the same order as in their general description in Chapter II.

1. Cliques: The village was divided into four cliques and a fifth group of isolates on the basis of sociometric data in response to an interview question about whom the villager sought for agricultural information. ("Have you talked with another farmer about agriculture in the last two months? If yes, with whom?") This question was asked because SINDI 1 simulates the diffusion of agricultural information of 2, 4-D weed spray. The cliques were delineated by plotting a sociogram on a map of the village (each member had a maximum of four sociometric choices. The peasants were categorized into cliques so most of the sociometric choices of a set of individuals went within (rather than outside) the clique. The intraclique choices tended to be spatially proximate individuals, providing support for spatial diffusion. However, in Colombian villages homes are located on the farms rather than in the village center. Table 1 indicates the number of members (NMEMCQ(ICQ)) in each clique for the number of cliques (NCLIQS) simulated.

Table 1. SINDI 1 Parameters by Cliques

Clique Number	Total Members	Tellers Channel Orientation			Total Tellers	Nontellers Channel Orientation		
		tellers	extension agent	teacher		tellers	extension agent	teacher
1	7	1	0	1	2	3	1	1
2	17	1	1	2	4	6	4	3
3	17	1	1	1	3	4	4	6
4	4	0	0	0	0	3	0	1
Isolates	11	0	0	0	0	0	7	4
Totals	56	3	2	4	9	16	16	15

2. External Channels: Two external interpersonal channels were chosen: (1) extension service agents, and (2) school teachers. In Colombia, the extension agent usually lives and has his office outside the village. His objective is to communicate new agricultural ideas to the villages he serves. The teacher lives in the village and has closer rapport with the villagers; however, a teacher serves as a change agent in a particular village for only a year or two. But, he generally has greater contact with the outside world than the average peasant. The extension agent sometimes works through the teacher in introducing new ideas to the community. Thus, it seemed appropriate to utilize the extension agent and school teacher as the chief channels of external innovation messages (NXCHAN = 2).

3. Channel Orientation: The degree to which each individual was oriented to either the two external interpersonal channels or one local interpersonal channel was determined from the relative frequency with which he reported having communicated with any of the three channels in the past year. For instance, an individual in Pueblo Viejo may have reported four communications with the teacher, and three contacts with the extension agent, his channel orientation would be the teacher. Table 1 indicates the channel orientation (CHANOR(IN)) of individuals in each clique.

4. External Channel Contact: Each message introduced through a channel in a time period reaches a specified number of people. The number of villager contacts made by the extension agent (referred to as "channel 1" from now on) was, for the purpose of these runs, estimated at three per time period (i.e., per year), and the number of contacts by the school teacher ("channel 2") at six per time period. Thus,

NXCCON(1) = 3 and NXCCON(2) = 6 in this simulation. While the extension agent makes relatively few trips to the village per year, the school teacher resides there and should, therefore, make more interpersonal contacts about an innovation.

5. Probability of Becoming a Knower form an External Channel: This probability (PKWXCH(INCHNL,ICH)) was calculated on the basis of the amount of interpersonal communication each peasant reported with each channel. Eighteen villagers were primarily oriented to channel 1, the extension agent. These 18 peasants had a total of 34 contacts with channel 1 and 17 contacts with channel 2. The information transfer probability was arbitrarily set, given primarily a channel 1 orientation, at .50. The probability of learning about an innovation from channel 2, given a channel 1 orientation, is 17/34 x .50 = .25. The 19 villagers oriented primarily to channel 2, the teacher, made 55 contacts with channel 2 and only 10 contacts with channel 1. Thus, for those oriented primarily to channel 2, the probability of becoming a knower about the innovation from channel 2 is arbitrarily .50, and the probability of awareness from channel 1 is .10. The remaining 32 peasants in the village had no contact with either the extension agent or teacher channels. Table 2 shows the values for this parameter.

Table 2. Information Transfer Probability Matrix from External Channels

Individual's Orientation	Message Channel 1	Message Channel 2
1	.50	.25
2	.10	.50

6. Local Interpersonal Channels: This is the same as the number of tellers (opinion leaders) in the village (NTELRS). An opinion leader was an individual who received three or more sociometric choices as sources of agricultural information. For the Pueblo Viejo data NTELRS = 9. See Table 1.

7. Teller Contacts: NTLCON was originally set at 30 contacts per year, based on the number of reported opinion leader contacts contacted plus the number of contacts each received. However, subsequent sensitivity checks revealed that 20 contacts in the model produced output which better approximates reality.

8. Probability of Becoming a Knower when Contacted by a Teller-Knower: For each clique, it was necessary to determine the probability of a nonknower becoming aware of the new idea upon contact with a knower-teller of his clique (PKWTLR(ICQ,ITELCQ)). This probability in clique 1 is .58. The procedure for estimating this probability was first to count the total number of reported sociometric contacts between the opinion leaders and the non-leaders in clique 1, which is seven. Then the total number of possible contacts in clique 1 between the two opinion leaders and the five other clique members was calculated, which is 12 (two possible contacts for each of the five non-opinion leaders and one each for the opinion leaders). Therefore, the probability given a contact of a nonknower learning from a knower-teller in clique 1 was 7/12 or .58.

In a similar fashion, the probability for a nonknower learning from a knower-teller in clique 2 is 13/64 or .20, and for clique 3 the probability is 11/48 or .23. There are no opinion leaders in clique 4 or for the isolates, so there is a zero probability of learning of the innovation in such a way.

The probability that a person in one clique will become a knower upon contact with a knower-teller in another clique, is restricted to only two cliques with mutual contacts, cliques 2 and 3. The probability of interclique contact was calculated in an analagous fashion to the calculation of the within-clique probability. The total number of peasants in clique 2 contacted by knower-tellers in clique 3 is 5, while the total number of possible contacts is 51. Therefore, the probability of clique 2 members being contacted by clique knower-tellers in group 3 is .10. Similarly, the probability of contact of clique 3 members by clique 2 knower-tellers is 6/68 or .09. See Table 3.

Table 3. Information Transfer Probability Matrix from Teller Contacts

Individual's Clique	Teller's Clique 1	2	3	4	5
1	.58	.00	.00	.00	.00
2	.00	.20	.10	.00	.00
3	.00	.09	.23	.00	.00
4	.00	.00	.00	.00	.00
5	.00	.00	.00	.00	.00

Processing Parameters

The values of the processing parameters were generally changed for different series of runs and are reported in the results section. However, for a few of the parameters we used similar values every run. NTIMPS was set to 15 for every run; we usually suppressed detailed printouts to save computer time and so NPRINTS was set to zero; in the runs at Michigan State University using a CDC 3600 computer, the values for the logical units parameters, LUNI, LUNO, and LUNP were always set to 60, 61, and 62 respectively.

State and Output Variables

The values for these variables are determined in the course of the simulation and are reported in the results section.

Preassignment of Individuals in the Simulation

Prior to each run, seven members of the community are preassigned as knowers. The reason for this preassignement is as follows. These early knowers learned over an 18 year time period ranging from 1935-1953. The model does not purport to explain the process by which these individuals first heard. The social system itself would have changed considerably in the 28-year (1935-1963) time period covered by the Colombia data. The model does not take into account dynamic changes in the structure nor the membership of the social system.

It is necessary to point out that four of the seven individuals are tellers. Preassignment of four tellers has the effect of creating four additional local interpersonal channels in the simulation every time period, regardless of how many knowers are activated.

In Pueblo Viejo, at the time of data collection, there were 56 knowers (84% of the farmers interviewed). Included among the knowers were 22 isolates, 11 of whom were oriented to one of the two external interpersonal channels. The remaining 11 isolates were not oriented to any channel--but 10 of the 11 did become knowers. Because the SINDI 1 model makes the assumption that individuals become knowers only when oriented to one of the external channels or to a local teller, the remaining 11 tellers could never become knowers in the simulation. Since our simplistic channel division was not isomorphic with the real world the 11 were dropped from inclusion in the simulation, and were also excluded from real world data comparisons. Thus, the total possible knowers in the reality data is 46 (i.e., the 56 out of the 67 possible farmers who were knowers at the end of the measurement period, minus the 11 isolates); in the simulation there are 56 possible knowers (i.e., 67 minus the 11 isolates because there is no restriction of when "measurement" of new knowers stops).

SIMULATION RUNS OF SINDI 1

The SINDI 1 runs provide as output a distribution of new knowers per time period over a series of time periods. Since per year data provide the basis for the calculations of the program's parameters, the simulation results are a rough approximation of the annual rate of diffusion of information.

To compare the simulation with the Colombia data used for validation, SINDI 1 was run 45 times; each 15 runs (i.e., for each new problem) the parameter settings were altered. The three sets of parameters for the data reported were determined from a number of earlier sensitization checks. (A brief description of the tests follows this section.) The OUTPUT routine was flagged to print summary statistics after each 15 runs. The results (as indicated in Figure 4) show that three series of settings approximate the reality-data curve. The model responded broadly to any alteration of the teller contact parameter, i.e., decreasing or increasing the number of contacts allowed an activated teller affects the rise between the fourth and tenth time periods more than the curve at the bottom of the "S." Altering the external channel contact parameter, i.e., increasing or decreasing the number of contacts allowed each external channel, has more effect early in the simulation; the more tellers it activates the closer the upper end of the simulated curve eventually approaches the reality data. It is important to remember here that four tellers are always preset as knowers; this effectively creates four additional local channels at the start of the simulation--a total of six channels with the external channels.

Comparison of the three simulation period curves with the realty curve indicates the results during the preliminary trials did not replicate both the slow initial curve rise and the high number of total knowers at the top of the S curve. SINDI 1 does come to within 5% of the total number of knowers with parameter settings of 20 teller contacts per year, and three contacts for channel one and six contacts for channel two. Because the simulated curve using the 20/3/6 settings came closest to the total number of actual knowers, another series of runs were processed in order to determine variance around a mean number of new knowers attributable to the random sampling.

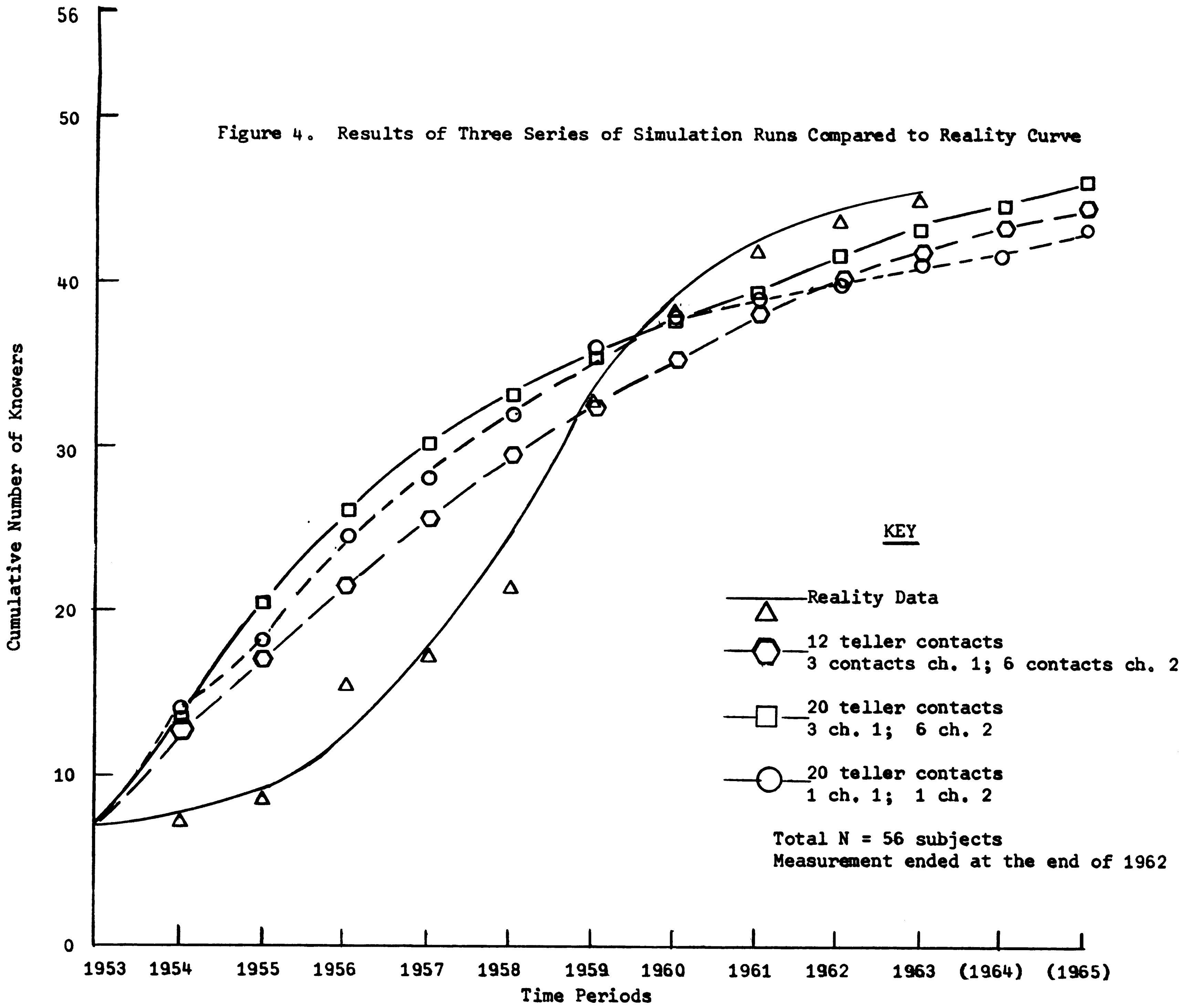


Figure 4. Results of Three Series of Simulation Runs Compared to Reality Curve

Final Runs of SINDI 1 Using the Colombia Data

For the final runs, SINDI 1 was run 5, 10, 20, and 40 times using the 20/3/6 settings. Twenty runs seemed the optimal number of runs to use for the general model. They provided a minimal amount of variance around the mean number of new knowers based on the use of our pseudo-random number generator and considering the cost of computer running time. That is, even though 40 runs provided somewhat less variance, the cost of relative computer time between 20 and 40 runs outweighed the small amount of variance decrease attributable to the larger number of runs. The results of the 20 runs are shown in Figure 5.

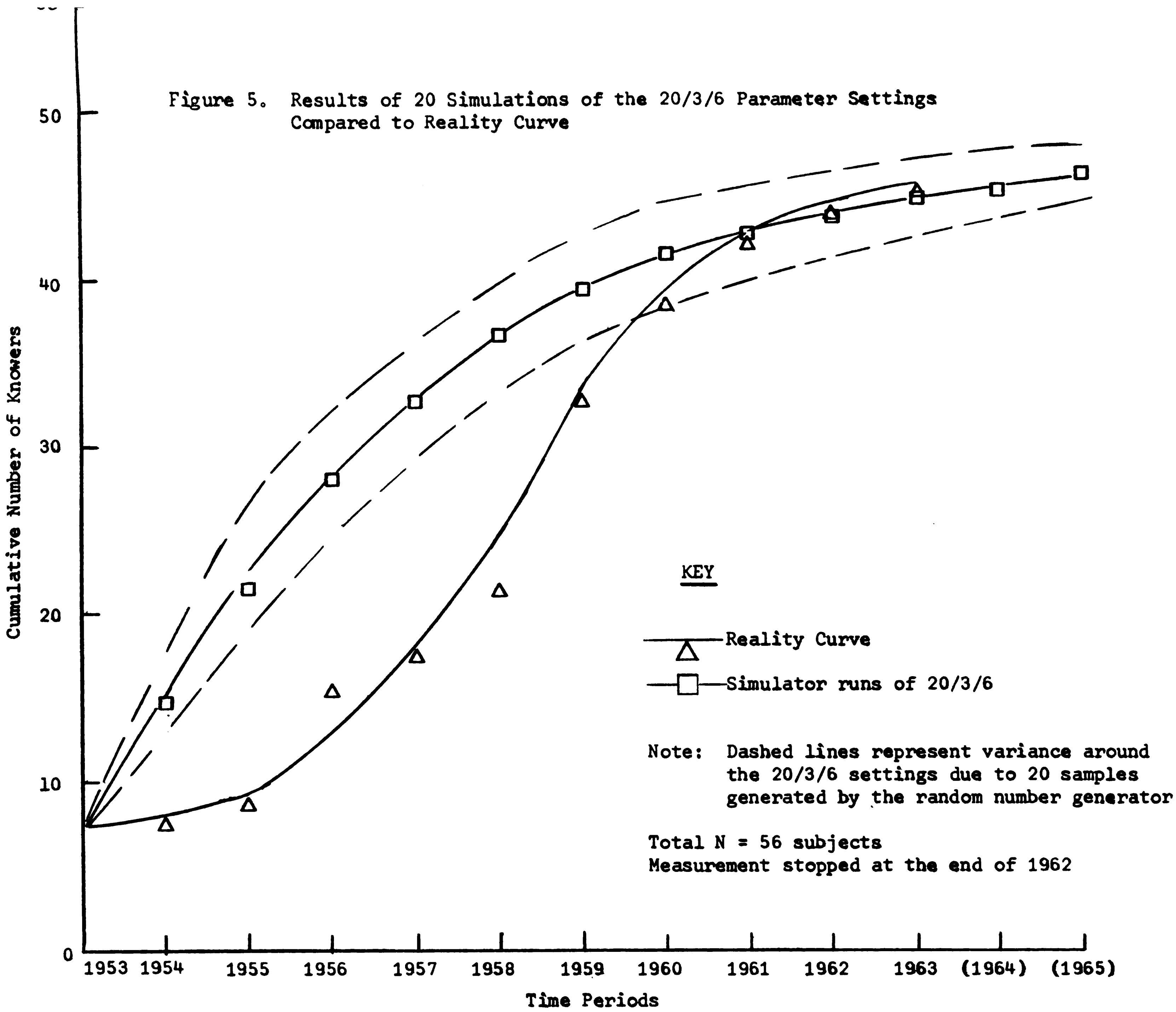
The Kolmogorov-Smirnov goodness-of-fit-test for two samples (the average number of new knowers from the 20 runs and the reality data) was applied to the two curves. This test indicates the two distributions differ more than could be due to chance from 1954 to 1960.

Shape of the Simulated Curves

Notice that the final curve, like the others, does not have the rapid initial rise of the reality curve, it is essentially linear. However, this almost linear curve may have some isomorphism with reality. Support for this statement comes from Coleman, Katz, and Menzel (1957); Coleman (1964); and Rainio (1961).

Coleman, Katz, and Menzel (1957) studied the diffusion of new drugs among socially isolated and socially integrated doctors. They found that "social location," that is, the frequency of contact with other doctors in the medical community for social or discussion purposes, was the cause of the difference between drug adoption between the two

Figure 5. Results of 20 Simulations of the 20/3/6 Parameter Settings Compared to Reality Curve



types of doctors. The isolated doctors got their new drug information from salesmen and advertising--essentially a two-step flow of communication from opinion leader to follower. The two-step flow is similar to that modeled in SINDI 1. The integrated doctors who received new drug information from various sources can be likened to participating in a multi-step flow of communication. It is interesting to note that the distribution cumve for the isolated doctors (and the two-step flow) is almost identical in shape to our simulated curve, while the distribution curve for the integrated doctors is more similar to the S shape of the reality data curve.

Coleman (1964) discussed the linear curve for the isolated doctors in terms of a "constant-source" diffusion process. This means that all diffusion of information proceeds from a constant source of information--independent of how many knowers there already are in the population. This process also presumes a limited population, and the number of new knowers per time period is then proportional to the number of nonknowers remaining. Relating this to the SINDI 1 model, we see there is a close analogy. SINDI 1 also has relatively constant sources of information; the model begins with two external channels and four preset tellers; once the five additional tellers are activated the sources are constant. Also, in the simulation, as time proceeds there are less available nonknowers and the number of new knowers each time period decreases accordingly. It appears that SINDI 1 is a better model of a constant source diffusion process than the Pueblo Viejo diffusion process.

Rainio (1961) discusses a Monte Carlo model of interaction based on laws of learning. For Rainio's model, the probability of learning information changes for each individual depending on the contacts he has. If the contact is rewarding the probability increases (analogous to reinforcement) if the contact is punishing the probability decreases (analogous to negative reinforcement). However, these probabilities are based on groups of individuals--that is the learning by an individual depends on the amount of learning by the group. Further, the amount to be learned depends on the amount remaining to be learned by the group. The notion of group learning produces an essentially linear learning curve, which rises faster than our simulated curve.

SENSITIVITY CHECKING

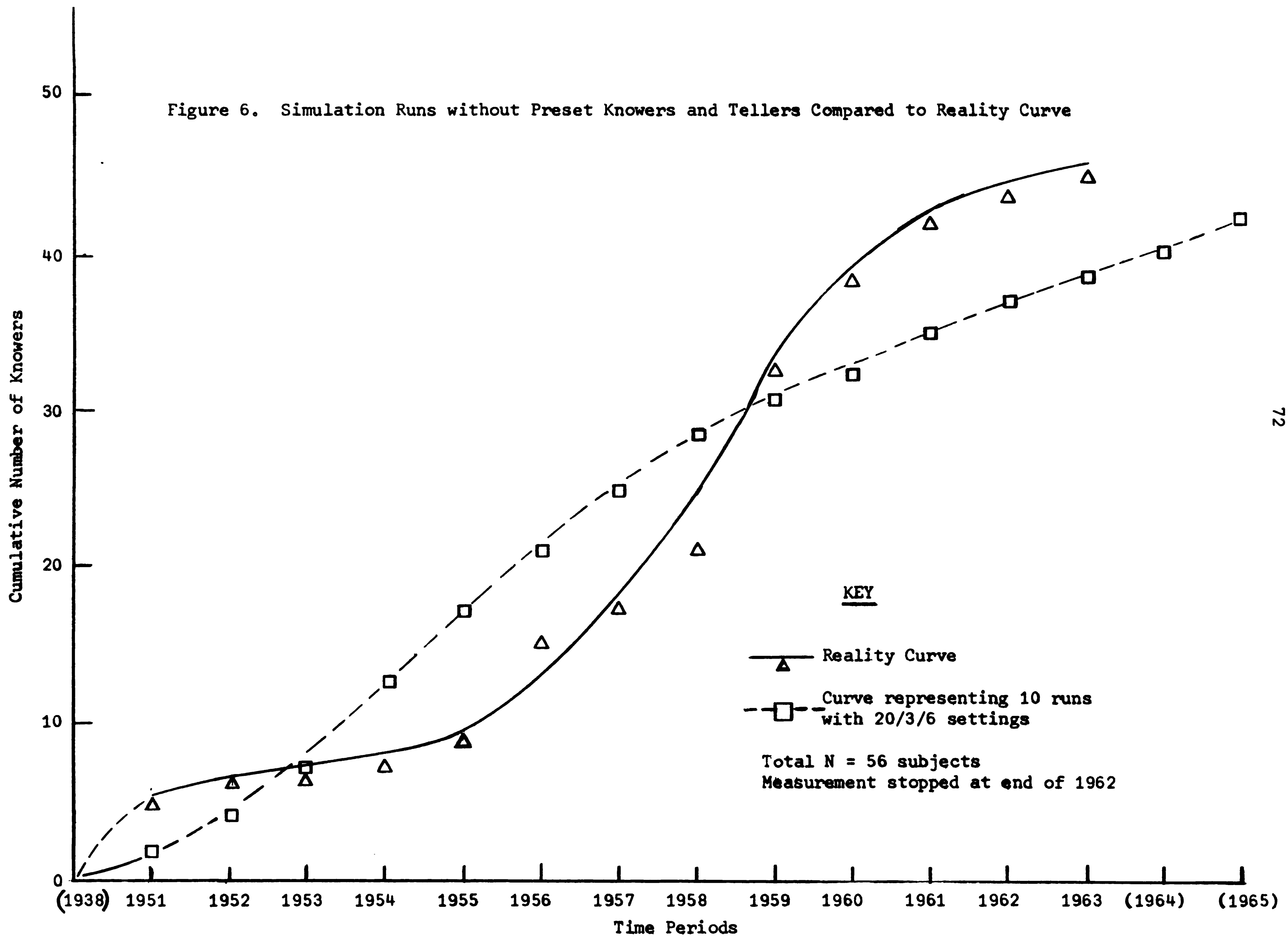
Various sensitivity checks of SINDI 1 revealed that the teller contact parameter (NTLCON) was the most sensitive of the two contact parameters. As mentioned previously, the external channel contact parameter (NXCCON(ICH)) seemed to have more affect on the initial rise of the curve, and the total number of knowers activated. Its initial influence in the final distribution is explainable, of course, because the external channels are the first channels-sources allowed to make contacts in the simulation. Since they make fewer contacts per time period than a teller, they have a lower probability of activating knower-tellers. Eventually, as the external channels activate knowers, the number of knower-tellers increases, and the tellers begin activating more knowers because of the greater number of contacts they are allowed each time period.* For instance, if six tellers are active, a total of 120 contacts per time

*New teller-knowers are not allowed to make contacts until one time period after their activation.

period is made--compared to nine total contacts for the external channels. Thus, after the first four time periods or so, the effects of the teller contacts become very significant.

However, the effect of this greater influence in the distribution by the teller contacts is mediated by two factors. First, the external channels have a higher probability (see Table 2) of transmitting information to individuals. The probability is never below .10. On the other hand, the probabilities for the various tellers (depending on their clique) of transmitting information are much lower (see Table 3), and are frequently zero. Second, the four preset tellers give the teller contact routine a constant advantage of 80 contacts per time period. But, the preset tellers are equally spread between the first three cliques (one each in cliques one and two; two tellers in clique three). Only for the first clique's members, for the teller-contacts from clique one, is the probability of information transfer high, it is zero for the rest of the cliques; for the tellers in cliques two and three there are low probabilities of information transfer by members in those same cliques, and zero probabilities for members from all other cliques. The effect of these 80 contacts is not as great as might be imagined though. Figure 6 shows the curve of ten runs without preset tellers and knowers using the 20/3/6 parameter settings. Notice that it is exactly the same shape as the other simulated curves (in Figure 4) but drops much lower than any of the other curves during the last five time periods; it appears to average about six knowers less than the closest simulated curve with preset knowers (including knower-tellers).

Figure 6. Simulation Runs without Preset Knowers and Tellers Compared to Reality Curve



However, there is greater variance of the mean number of new knowers per time period (standard error of the mean) for the ten runs without preset knowers than for ten runs with preset knowers. Especially between the third and tenth time period, the variance for the runs without preset knowers is almost double the variance for the runs with preset knowers. This difference, of course, is because in the preset runs there is less random variation of when tellers are activated due to four out of nine tellers being activated by the first time period.

The only two parameters that we have changed during sensitivity checks to date are the channel contact parameter and the teller contact parameter. NXCCON(ICH) was varied from 1-1 (1 contact per time period for channel 1, and 1 for channel 2) to 3-6; 6-6; 6-12; 12-24; and 24-24. The NTLCON was varied from 12, 20, 30, 40, to 50 contacts per time period, with 20 contacts chosen as the best setting for the simulation in terms of output matching reality. The following generalizations may be made regarding the variation of these parameters:

1. The higher the teller contact parameter is set, the higher the rise of the simulated curve between the second and eighth time periods.

2. Higher teller contact settings have little effect on the eventual number of total knowers.

3. The lower the teller contact setting, the better the simulated curve fits the reality curve during the first seven time periods.

4. A lower teller contact setting has negligible effect on the total number of knowers.

5. As the teller contacts increase, the shape of the curve becomes more "S" shaped, but its initial rise still is much greater than the reality data curve.

6. As the number of external channel contacts increase, so does the eventual total number of knowers.

7. An increase or decrease in the number of external channel contacts affects the average number of new knowers the same way in all time periods, i.e., changing the parameter does not affect the shape of the simulated curve, only its height.

8. There is no difference between the amount of channel contacts allowed one channel over another; the difference is only significant in the sense that it affects the total number of external channel contacts allowed.

Recommendations for future sensitivity checking with the general model are included in the next chapter.

CHAPTER V

CONCLUSION

This chapter offers a critique of the SINDI 1 model. Another section makes recommendations for future research with the SINDI 1 model. The chapter ends with a summary description of SINDI 1.

CRITIQUE

Figure 4 shows that there is little goodness-of-fit between the simulated curves and the reality curves overall, although they do approach each other at the end of the ten time periods. What accounts for this difference? There are two major reasons: conceptual inequivalence between model and reality and parameter estimation.

Conceptual Inequivalence

The following specific criticism may be made.

1. SINDI 1 does not model the psychological processes involved in accepting information (such as Hägerstrand's psychological resistance concept). In actual application to an innovation diffusion process there may be a time lag between information awareness and final adoption--individuals may not pass on innovation information until the final adoption stage. Also, given a contact is unsuccessful with an individual, the probability of his accepting information during the next contact does not change--he doesn't learn.

2. The model treats opinion leadership dichotomously instead of as a matter of degree. That is, either a person is allowed to contact

nonknowers, or he isn't. In actuality, some individuals have more contacts with nonknowers than other individuals. This is not an either/or process and knowers in the simulation should probably not be restricted from contacting individuals completely.

3. The information seeking behavior regarding tellers is unrealistic. In SINDI 1, the tellers contact individuals, but nonknoers are not allowed to seek out tellers. This assumes active opinion leadership only and neglects passive opinion leadership for which there is empirical support.

4. SINDI 1 assumes that tellers make random contacts with individuals. Although we don't completely understand this notion in diffusion research conceptually, it is true that active opinion leaders seek out their nonknower contacts, and do not "waste" contacts with individuals who already know. In other words their contacting behavior is not random. (The data for Pueblo Viejo indicated certain individuals regularly had more contacts with opinion leaders.) Further, the information transfer probabilities are not really contact probabilities for everyone has an equal chance of being contacted due to random selection.

5. The model allows for only <u>one</u> type of channel orientation for each individual. Persons may be equally oriented to two channels and thus have a higher probability of accepting information than someone oriented to only one channel.

6. There appears to be heavy emphasis in the model on system statics rather than system dynamics, i.e., it emphasizes ascertaining the final values of entities rather than continuous change variables. A continuous change model would permit the simulation to change

continuously as time advanced--the decision rules would change and the simulation would be adaptive. This would be especially useful, for example, in modeling the curve of change agent activity (Rogers, 1962, p. 259) against the diffusion curve. The change agent activity rises initially and then falls off as the diffusion process increases. This problem, however, is indicative of the general problem of modeling change activity.

Parameter Estimation

As mentioned in earlier chapters, most of the general parameters were very arbitrarily set. For example, there seems little rationale for channel contact probabilities based on an arbitrary value of .50.; the method for dividing the village into cliques is imprecise; the restriction of the number of external interpersonal channels (limited to two) seems severe, for it neglects the influence of visitors or families from outside of the community. Further, with the Pueblo Viejo data if an individual disclosed equal contacts with two channels, he was randomly assigned to one of them (see criticism #5, above).

There is also a problem due to the data gathering methods of the Colombia data. Since it relies on recall, there are a number of discrepancies in the reality diffusion curve which could affect the simulated output comparison. It may be true, that just because the curves don't match overall, that the data are faulty and the curve actually does represent the true diffusion curve.

RECOMMENDATIONS FOR FUTURE RESEARCH WITH SINDI 1

1. Change the NTLCON setting into an array equal to the number of tellers in the simulation with a different number of contacts apiece. This relates to criticism #2, above.

2. Run the simulation a number of times changing the information transfer probabilities, to determine how sensitive these are.

3. Collect specific data congruent with the model's structure, and then run the simulation for additional comparisons with reality data.

4. Perhaps add a learning probability matrix to be used in comparison with the information transfer probability matrix. That is, the probability of an individual accepting information would be calculated to increase with the number of unsuccessful contacts he has had.

5. An interaction effect should also be modeled. Somewhat similar to Rainio's (1961) model of group learning, the probability of the remaining nonknowers becoming knowers would increase proportionally with the number of knowers in the social system. In SINDI 1 this probability does not change. This probability would change of course, if everyone (instead of just nine individuals) was a potential teller and once activated could tell anyone else innovation information.

CONCLUDING REMARKS AND SUMMARY

Stanfield, Lin, and Rogers (1965, p. 22) state:

> Peasant villages provide obvious advantages as locales for Monte Carlo diffusion simulations: the basic, primitive nature of communication behavior as compared to the mass media saturated nature of other locales, the localistic

> tendency of peasants which emphasizes the sharpness of village boundaries and results in relatively few communication channels by which innovations enter the village from external sources, and the relatively small number of individuals involved.

In one manner of speaking these advantages seem attractive, especially when it appear we are modeling an almost closed system. However, it is this apparent attractiveness which may lead to oversimplification of a model.

Thus, the statement that the advantage of computer modeling is the ability of the computer to systematically vary relationship and variables more readily than a human could hope to, ought to be qualified. The computer may be an efficient model manipulator, but <u>the practical limitations of time, money, and programming skills are very real drawbacks to the simulation technique which tend to lead to oversimplification</u>.

We suggested two objectives in the beginning of this report: building a predictive tool and possibly adding refinements to diffusion theory. How well have we met these objectives?

We can't be certain yet that we have a useful predictive tool with SINDI 1. It hasn't been utilized with enough real data to make this estimation. That it simulates an information diffusion curve fairly well, we know. Just how well and what conclusions may be drawn from the simulated effects remain to be tested.

On the other hand, the model did force us to look closely at a number of theoretical assumptions in diffusion we were willing to take for granted: it forced us to state these assumptions in explicit terms; and it forced us to look closely at the interaction of four variables. In our case, we found that diffusion research had little to say about the probability of information imparting and acceptance by an individual, and we had to come to grips with this problem. Thus, SINDI 1 has (a) exposed missing links in a theory--the information acceptance concept, and (b) allowed consideration of alternative hypotheses--the hypothesis of diffusion as learning, for example. Future researchers, following these leads, may alter some of the generalizations found in the diffusion literature today.

There is another utility to building the SINDI 1 model, though. It is in providing a working example of simulation to diffusion researchers. By using the model, researchers can become familiar with Monte Carlo simulation techniques; they can also realize that simulation may be an expensive and time consuming procedure which must be weighed against alternative methods of modeling.

Summary

This report has discussed the use of simulation techniques in diffusion research. SINDI 1, based on theories of Hägerstrand (1967), Karlsson (1958), and Deutschmann (1962a, 1962b, 1962c), is a stochastic computer model of the diffusion of information about an innovation. The validation data, and the data used to arrive at parameter values, were from Rogers' (1965) research in Pueblo Viejo, a small Colombian peasant village. Messages about the innovation enter the village through external interpersonal channels. In SINDI 1 there are two such channels, one representing an extension agent, the other representing the school teacher who has an urban, rather than local orientation. Mass media channels were not important in SINDI 1 because the villages are largely illiterate and not exposed to relevant agricultural radio programs.

During the simulation each interpersonal channel randomly contacts members of the village. Because of the selectivity processes, some members are more inclined to obtain information from one channel than another; thus an individual's probability of information transfer will be higher for one channel than another. The peasants are divided into four cliques and one clique of isolates. Local communication flows more frequently within cliques than between cliques; and individuals have a higher assigned probability of receiving information from like-clique members. However, there is a small group of individuals, known as "tellers" (the opinion leaders discussed previously), who are in three of the cliques; they have a high probability of passing on information to <u>any</u> other members of the community, after they become knowers.

Following description of the model, results obtained from various runs were discussed, and criticisms, recommendations, and conclusions were made.

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APPENDIX A

SINDI 1 PROGRAM LISTING

```
      PROGRAM SINDI1
C     VERSION 1.5  (9/29/68)  PROGRAMMED BY GERHARD J. HANNEMAN
      DIMENSION RANIND(100), PROB(100), CHANOR(100), CLIQUE(100), TELLER
     1(100), TLRKWR(100), KNOWER(100), CHNSOR(100), TELSOR(100), NMEMCQ(
     25), PKWXCH(5,5), PKWTLR(5,5), NXCCON(5), KNOTLY(5), KNOSUM(5), AVI
     3KWR(100,30), MEAN(30), STDEV(30), DUMARR(30), IRAND(10)
      COMMON /ARRAYS/ RANIND,PROB,CHANOR,CLIQUE,TELLER,KNOWER,CHNSOR,TEL
     1SOR,NMEMCQ,NXCCON,KNOTLY,KNOSUM,AVIKWR,MEAN,STDEV,DUMARR,TLRKWR,PK
     2WXCH,PKWTLR
      COMMON /VARIBL/ NPROBS,NRUNS,NTIMPS,NXCHAN,NCLIQS,NPRINT,LUNI,LUNO
     1,LUNP,LUN1,NCUMEV,NEVENT,NTELAC,NTLCON,TOTIND
      COMMON /INDEX/ ITIME,IP,NTELRS,XCHTEL
      REAL MEAN
      INTEGER CHANOR,CLIQUE,TELLER,TLRKWR,CHNSOR,TELSOR,DUMARR,RANIND,TO
     1TIND,TEL,XCHTEL
C          LOGICAL UNIT ASSIGNMENT AND PARAMETER SETTING
      LUNI=60
      LUNO=61
      LUNP=62
      NPROBS=1
C          THIS IS THE LOOP WHICH CYCLES THE PROGRAM  THROUGH THE NUMBER
C          OF PROBLEMS DESIGNATED BY THE NPROBS PARAMTER.
      DO 100 IP=1,NPROBS
      TOTIND=0
C          INPUT READS IN PARAMETER VALUES AND INITIALIZES ARRAYS
      CALL INPUT
C          THIS LOOP IS FOR THE NUMBER OF RUNS BEING SIMULATED
      DO 90 IR=1,NRUNS
      DO 10 IN=1,TOTIND
      CHNSOR(IN)=0
      TLRKWR(IN)=0
      TELSOR(IN)=0
   10 KNOWER(IN)=0
      KNOWER (1)=TLRKWR(1)=1
      KNOWER (3)=TLRKWR(3)=1
      KNOWER(7)=TLRKWR(7)=1
      KNOWER (9)=TLRKWR(9)=1
      KNOWER(10)=1
      KNOWER(13)=1
      KNOWER(36)=1
      DO 20 ICQ=1,NCLIQS
   20 KNOSUM(ICQ)=0
      KNOSUM(1)=3
      KNOSUM(3)=4
      NCUMEV=7
      NTELAC=0
```

```
      IF (NRUNS-NPRINT) 30,30,40
   30 WRITE (LUNO,110) IR,IP
      WRITE (LUNO,130) ,(ICQ,ICQ=1,NCLIQS)
C           THIS LOOP IS FOR THE NUMBER OF TIME PERIODS BEING SIMULATED.
   40 DO 90 ITIME=1,NTIMPS
      NEVENT=0
      DO 50 ICQ=1,NCLIQS
   50 KNOTLY(ICQ)=0
      IF (NRUNS-NPRINT) 60,60,70
   60 WRITE (LUNO,120) ITIME
C           SUBROUTINE EXTMES IS THE EXTERNAL CHANNEL CONTACT ROUTINE.
   70 CALL EXTMES
C           SUBROUTINE TELCON IS THE TELLER CONTACT ROUTINE.
      CALL TELCON
C           THIS LOOP UPDATES THE TELLER-KNOWER LIST AFTER EXTMES AND
C           TELCON HAVE MADE ALL OF THEIR ALLOWED CONTACTS.
      DO 80 IN=1,NTELRS
      TLRKWR(IN)=0
   80 IF (KNOWER(IN).EQ.1) TLRKWR(IN)=1
   90 CONTINUE
      CALL OUTPUT
  100 CONTINUE
C
  110 FORMAT (1H1,25HO U T P U T   S E C T I O N,///33X, 36HTHESE ARE DE
     1TAILED RESULTS FROM RUN ,I2, 12H OF PROBLEM ,I2,  1H.)
  120 FORMAT (//,3X,I3)
  130 FORMAT (1H0,70X,10HSUCCESSFUL,5X,12HUNSUCCESSFUL/72X,8HCONTACTS,6X
     1,8HCONTACTS/6H  TIME,2X,9HEVENTS IN,2X,5HCUML.,2X,5HCUML.,10X,17HK
     2NOWERS BY GROUPS,20X,3HNEW,21X,11HINFO TRANS ,2X,11HEVENT       ,/,
     37H PERIOD,2X,6HPERIOD,3X,14HEVENTS TELLERS,5(2X,I2,3X),16H  SOURC
     4 KNOWERS,2X,15HSOURCE RECEIVER,2X,11HPROBABILITY,2X,11HPROBABILIT
     5)
      END
```

```
      SUBROUTINE INPUT
      DIMENSION RANIND(100), PROB(100), CHANOR(100), CLIQUE(100), TELLER
     1(100), TLRKWR(100), KNOWER(100), CHNSOR(100), TELSOR(100), NMEMCO(
     25), RKWXCH(5,5), RKWTLR(5,5), NXCCON(5), KNOTLY(5), KNOSUM(5), AVT
     3KWR(100,30), MEAN(30), STDEV(30), DUMARR(30)
      COMMON /ARRAYS/ RANIND,PROB,CHANOR,CLIQUE,TELLER,KNOWER,CHNSOR,TEL
     1SOR,NMEMCO,NXCCON,KNOTLY,KNOSUM,AVTKWR,MEAN,STDEV,DUMARR,TLRKWR,R
     2WXCH,RKWTLR
      COMMON /VARIBL/ NPROBS,NRUNS,NTIMPS,NXCHAN,NCLIQS,NPRINT,LUNI,LUNO
     1,LUNP,LUNT,NCUMEV,NEVENT,NTELAC,NTLCON,TOTIND
      COMMON /INDEX/ ITIME,IP,NTELRS
      REAL MEAN
      INTEGER CHANOR,CLIQUE,TELLER,TLRKWR,CHNSOR,TELSOR,DUMARR,RANIND,TO
     1TIND
C         DESCRIPTION OF PROGRAM
      WRITE (LUNO,110)
C         DESCRIPTION OF CURRENT PROBLEM
      READ (LUNI,120) ,(DUMARR(K),K=1,18)
      WRITE (LUNO,130) ,IP,(DUMARR(K),K=1,18)
C         INPUT NUMBER OF PROBLEMS, RUNS, DETAILED PRINTOUTS,TIME
C         PERIODS, EXTERNAL CHANNELS, CLIQUES, AND MEMBERS IN EACH CLIQU
      READ (LUNI,140) ,NPROBS,NRUNS,NPRINT,NTIMPS,NXCHAN,NCLIQS,(NMEMCO(
     1ICQ),ICQ=1,NCLIQS)
      WRITE (LUNO,150) ,NRUNS,NTIMPS
      WRITE (LUNO,160) ,(ICQ,NMEMCO(ICQ),ICQ=1,NCLIQS)
      DO 10 ICQ=1,NCLIQS
   10 TOTIND=TOTIND+NMEMCO(ICQ)
      WRITE (LUNO,170) NCLIQS,TOTIND
      IN=0
      ICHNLS=NXCHAN+1
C         LOOPS 40 AND 50 READ IN THE CHANNEL ORIENTATIONS FOR EACH
C         CLIQUE AND THEN ASSIGNS A CHANNEL ORIENTATION TO EACH INDIVID.
      DO 50 ITEL=1,2
      NTELRS=IN
      IF (ITEL.EQ.2) GO TO 20
      WRITE (LUNO,190) ,(ICH,ICH=1,NXCHAN)
      GO TO 30
   20 WRITE (LUNO,180) ,(ICH,ICH=1,NXCHAN)
   30 DO 50 ICQ=1,NCLIQS
      READ (LUNI,140) (DUMARR(ICH),ICH=1,ICHNLS)
      WRITE (LUNO,200) ICQ,(DUMARR(ICH),ICH=1,ICHNLS)
      DO 40 ICH=1,ICHNLS
      INCHOR=DUMARR(ICH)
      DO 40 K=1,INCHOR
      IN=IN+1
      CLIQUE(IN)=ICQ
```

```
      CHANOR(IN)=ICH-1
   40 CONTINUE
   50 CONTINUE
      DO 70 IT=1,NTIMPS
      DO 60 IN=1,TOTIND
   60 AVTKWP(IN,IT)=0.
      MEAN(IT)=0.
   70 STDEV(IT)=0.
C          THE WRITE STATEMENTS THAT FOLLOW PRINTOUT THE PARAMETERS IN
C          ORDER TO CHECK THAT THEY HAVE BEEN INPUT PROPERLY.
      READ (LUNI,140) NTLCON,(NXCCON(ICH),ICH=1,NXCHAN)
      WRITE (LUNO,210) NTLCON,(ICH,NXCCON(ICH),ICH=1,NXCHAN)
C          INFORMATION TRANSFER PROBABILITY MATRIX FOR EXTERNAL CHANNEL C
      WRITE (LUNO,220) ,(ICH,ICH=1,NXCHAN)
      DO 80 ICH=1,NXCHAN
      READ (LUNI,230) ,(PKWXCH(ICH,JCH),JCH=1,NXCHAN)
      WRITE (LUNO,240) ,ICH,(PKWXCH(ICH,JCH),JCH=1,NXCHAN)
   80 CONTINUE
C          INFORMATION TRANSFER PROBABILITY MATRIX FOR TELLER CONTACT
      WRITE (LUNO,250) ,(ICQ,ICQ=1,NCLIQS)
      DO 90 ICQ=1,NCLIQS
      READ (LUNI,230) ,(PKWTLR(ICQ,JCQ),JCQ=1,NCLIQS)
      WRITE (LUNO,240) ICQ,(PKWTLR(ICQ,JCQ),JCQ=1,NCLIQS)
   90 CONTINUE
      WRITE (LUNO,260)
      DO 100 IN=1,TOTIND
      ITELL=2HNO
      IF (IN.LE.NTELRS) ITELL=3HYES
  100 WRITE (LUNO,270) IN,CLIQUE(IN),CHANOR(IN),ITELL
      RETURN
C
  110 FORMAT (1H1,17X,82HS I N D I I - - S I M U L A T I O N   O F   I N
     1F O R M A T I O N   D I F F U S I O N,//,120(1H*),/,120(1H*))
  120 FORMAT (18A4)
  130 FORMAT (1H0, 24HI N P U T   S E C T I O N,///28X, 23HPARAMETERS FOR
     1 PROBLEM ,I2, 4H -- ,18A4/)
  140 FORMAT (15I3)
  150 FORMAT (1H0,25X, 14HNUMBER OF RUNS,10X, 22HNUMBER OF TIME PERIODS,
     1/32X,I2,23X,I2)
  160 FORMAT (1H0,10X, 18HCLIQUE COMPOSITION,/13X, 14HNO.     MEMBERS,/(1
     13X,I2,9X,I2,/))
  170 FORMAT (5X, 8HTOTALS  ,I2,9X,I2)
  180 FORMAT (1H0,10X, 19HCHANNEL ORIENTATION,/15X, 11HNON-TELLERS,/11X,
     1 30HCLIQUE    NOM    EXT. CHANNELS,/13X,  3HNO.,5X,  4HCH 0,2X,10(
     2I2,2X))
  190 FORMAT (1H0,10X, 19HCHANNEL ORIENTATION,/15X, 11H  TELLERS  ,/11X,
```

```
     1 [illegible]          [illegible]     [illegible]XT, [illegible],/13X,  [illegible],[illegible]X,  [illegible]
     2I3,2X))
 [illegible] FORMAT (1H0,13X,I3,7X,I3,[illegible],10(I3,2X))
 21[illegible] FORMAT (1H0,26X, [illegible] OF TELLER CONTACTS,22X, [illegible]
     1TERNAL CHANNEL,/26X, 16HEACH TIME PERIOD,26X, 25HCONTACTS EACH TI
     2E PERIOD,/33X,I3,[illegible]X,I3/ [illegible] ,I3, [illegible],I3,2X))
 [illegible] FORMAT (1H1,10X, 30H INFORMATION TRANSFER PROBABILITY MATRIX,/11X,
     122HFROM EXTERNAL CHANNELS,/10X,10(I3,2X))
 [illegible] FORMAT (10F3.2)
 [illegible] FORMAT (1H0,13X,I3,2X,10(F4.2,2X))
 [illegible] FORMAT (1H0,10X, 30HINFORMATION TRANSFER PROBABILITY MATRIX,/11X,
     122HFROM TELLER CONTACTS,/10X,10(I3,2X))
 [illegible] FORMAT (1H1,10X, 30HINDIVIDUAL IDENTIFICATION LIST,/,10X, [illegible]
     1IDUAL   CLIENT   CHANGE   TELLER)
 27[illegible] FORMAT (1[illegible]X,I3,8X,I3,7X,I3,7X,A3)
       END
```

```
      SUBROUTINE EXTMES
      DIMENSION RANIND(100), PROB(100), CHANOR(100), CLIQUE(100), TELLE
     1(100), TLRKWR(100), KNOWER(100), CHNSOR(100), TELSOR(100), NMEMCQ(
     25), PKWXCH(5,5), PKWTLR(5,5), NXCCON(5), KNOTLY(5), KNOSUM(5), AVT
     3KWR(100,30), MEAN(30), STDEV(30), DUMARR(30)
      COMMON /ARRAYS/ RANIND,PROB,CHANOR,CLIQUE,TELLER,KNOWER,CHNSOR,TEL
     1SOR,NMEMCQ,NXCCON,KNOTLY,KNOSUM,AVTKWR,MEAN,STDEV,DUMARR,TLRKWR,PK
     2WXCH,PKWTLR
      COMMON /VARIBL/ NPROBS,NRUNS,NTIMPS,NXCHAN,NCLIQS,NPRINT,LUNI,LU
     1,LUNP,LUN1,NCUMEV,NEVENT,NTELAC,NTLCON,TOTIND
      COMMON /INDEX/ ITIME,IP,NTELRS,XCHTEL
      REAL MEAN
      INTEGER CHANOR,CLIQUE,TELLER,TLRKWR,CHNSOR,TELSOR,DUMARR,RANIND,TO
     1TIND,TEL,XCHTEL
C          KEY1 IS A KEY WHICH, WHEN SET TO 0, SUPPRESSES PRINTOUTS OF THE
C          UNSUCCESSFUL CONTACTS.
      KEY1=0
C          THIS LOOP CYCLES THE EXTMES ROUTINE AS MANY TIMES AS THERE ARE
C          CHANNELS.
      DO 60 ICH=1,NXCHAN
      IUP=TOTIND
      ILO=1
      IREP=1
C          THIS CALL TO RANDOM PRODUCES A LIST OF RANDOM INDIVIDUALS
C          EQUAL TO THE NUMBER OF CONTATCS ALLOWED ONE CHANNEL.
      CALL RANDOM (ILO,IUP,IREP,NXCCON(ICH))
      NCONT=NXCCON(ICH)
C          LOOP 60 IS FOR THE NUMBER OF CONTACTS ALLOWED ONE CHANNEL--THAT
C          IS, IT ITERATES THROUGH THE ENTIRE LIST OF RANDOM INDIVIDUALS
C          GENERATED BY THE CALL TO RANDOM.
      DO 60 KCONT=1,NCONT
      IN=RANIND(KCONT)
C          HERE THE INDIVIDUAL IS CHECKED TO SEE IF HIS CHANNEL ORIENTATIO
C          IS EXTERNAL AND HE IS NOT A KNOWER ALREADY.
      IF (CHANOR(IN).EQ.0) GO TO 50
      IF (KNOWER(IN).EQ.1) GO TO 50
      INCHNL=CHANOR(IN)
C          THIS IS THE COMPARISON OF THE INFORMATION TRANSFER PROBABILITY
C          WITH A RANDOM DECIMAL (CALLED PROB IN THIS LISTING INSTEAD OF
C          RANDF REFERRED TO IN THE TEXT).
      IF (PKWXCH(INCHNL,ICH)-PROB(KCONT)) 50,10,10
C          IF INFORMATION TRANSFERS, AN EVENT HAS OCCURRED--IF NOT, THE
C          NEXT RANDOM INDIVIDUAL IS CONTACTED.
   10 NEVENT=NEVENT+1
      NCUMEV=NCUMEV+1
      ICQ=CLIQUE(IN)
```

```
      KNOWER(IN)=1
      KNOILY(ICO)=KNOILY(ICO)+1
      KNOSUM(ICO)=KNOSUM(ICO)+1
   20 CHNSOR(IN)=ICH
      IF (NRUNS-NPRINT) 40,40,30
   30 AVINWR(IN,III  )=AVINWR(IN,III  )+1.
      GO TO 60
   40 TEL=3H
      IF (IN.LE.NTELRS) TEL=3HILR
      WRITE (LUNO,70) ICH,TEL,IN,PRWACH(INCHNL,ICH),PROB(KCOUNT)
      GO TO 60
   50 IF (KEY1.EQ.3) GO TO 60
      TEL=3H
      IF (IN.LE.NTELRS) TEL=3HTLR
      WRITE (LUNO,80) ICH,TEL,IN,PRWACH(INCHNL,ICH),PROB(KCOUNT)
   60 CONTINUE
      RETURN
C
   70 FORMAT (69X,  2HCH,I2,4X,A3,I5,23X,F5.3,9X,F5.3)
   80 FORMAT (85X,  2HCH,I2,3X,A3,I5,7X,F5.3,5X,F5.3)
      END
```

```
      SUBROUTINE TELCON
      DIMENSION RANIND(100), PROB(100), CHANOR(100), CLIQUE(100), TELLE
     1(100), TLRKWR(100), KNOWER(100), CHNSOR(100), TELSOR(100), NMEMCO
     25), PKWXCH(5,5), PKWTLR(5,5), NXCCON(5), KNOTLY(5), KNOSUM(5), AVT
     3KWR(100,30), MEAN(30), STDEV(30), DUMARR(30)
      COMMON /ARRAYS/ RANIND,PROB,CHANOR,CLIQUE,TELLER,KNOWER,CHNSOR,T
     1SOR,NMEMCO,NXCCON,KNOTLY,KNOSUM,AVTKWR,MEAN,STDEV,DUMARR,TLRKWR,P
     2WXCH,PKWTLR
      COMMON /VARIBL/ NPROBS,NRUNS,NTIMPS,NACHAN,NCLIQS,NPRINT,LUNI,LU
     1,LUNP,LUN1,NCUMEV,NEVENT,NTELAC,NTLCON,TOTIND
      COMMON /INDEX/ ITIME,IP,NTELRS,XCHTEL
      REAL MEAN
      INTEGER CHANOR,CLIQUE,TELLER,TLRKWR,CHNSOR,TELSOR,DUMARR,RANIND,T
     1TIND,TEL,XCHTEL
      KEY1=0
C         LOOP 70 CHECKS EACH TELLER TO SEE IF HE IS A KNOWER.  ONLY THE
C         TELLERS THAT ARE KNOWERS FROM PREVIOUS TIME PERIODS ARE ALLO
C         TO MAKE CONTACTS.
      DO 70 INTEL=1,NTELRS
      IF (TLRKWR(INTEL).EQ.0) GO TO 70
      IUP=TOTIND
      ILO=1
      IREP=1
      CALL RANDOM (ILO,IUP,IREP,NTLCON)
      ITELCO=CLIQUE(INTEL)
C         LOOP 60 ITERATES THROUGH THE LIST OF RANDOM INDIVIDUALS
C         GENERATED BY THE CALL TO RANDOM AND EQUAL TO THE NUMBER OF
C         CONTACTS ALLOWED A TELLER.
      DO 60 ITCON=1,NTLCON
      IN=RANIND(ITCON)
      ICO=CLIQUE(IN)
C         HERE THE INDIVIDUAL IS CHECKED TO SEE IF HE IS A KNOWER ALREAD
      IF (KNOWER(IN).EQ.1) GO TO 50
C         THIS IS THE COMPARISON OF THE INFORMATION TRANSFER PROBABILIT
C         WITH A RANDOM DECIMAL (CALLED PROB IN THIS LISTING INSTEAD OF
C         RANDF REFERRED TO IN THE TEXT).
      IF (PKWTLR(ICO,ITELCO)-PROB(ITCON)) 50,10,10
C         IF INFORMATION TRANSFERS, AN EVENT HAS OCCURRED--IF NOT, THE
C         NEXT RANDOM INDIVIDUAL IS CONTACTED.
   10 NEVENT=NEVENT+1
      NCUMEV=NCUMEV+1
      KNOWER(IN)=1
      KNOTLY(ICO)=KNOTLY(ICO)+1
      KNOSUM(ICO)=KNOSUM(ICO)+1
      TELSOR(IN)=INTEL
   20 IF (NRUNS-NPRINT) 40,40,30
```

```
30  AVTKWR(IN,ITIME)=AVTKWR(IN,ITIME)+1.
    GO TO 60
40  TEL=3H
    IF (IN.LE.NTELRS) TEL=3HTLR
    WRITE (LUNO,120) INTEL,TEL,IN,PKWTER(ICO,ITELCO),PROB(ITCON)
    GO TO 60
50  IF (KEY1.EQ.0) GO TO 60
    TEL=3H
    IF (IN.LE.NTELRS) TEL=3HTLR
    WRITE (LUNO,140) INTEL,TEL,IN,PKWTER(ICO,ITELCO),PROB(ITCON)
60  CONTINUE
70  CONTINUE
    IF (NRUNS-NPRINT) 100,100,80
80  CUMKWR=0.
    DO 90 ICO=1,NCLIOS
    DUMMY=FLOAT(KNOSUM(ICO))
90  CUMKWR=CUMKWR+DUMMY
    MEAN(ITIME)=MEAN(ITIME)+CUMKWR
    STDEV(ITIME)=STDEV(ITIME)+CUMKWR*CUMKWR
    GO TO 110
100 WRITE (LUNO,130) NEVENT,NCUMEV,NTELAC,(KNOTEL(ICO),KNOSUM(ICO),ICO
   1=1,NCLIOS)
110 RETURN
C
120 FORMAT (68X,   3HTLR,I3,2X,A3,I3,23X,F5.3,9X,F5.3)
130 FORMAT (11X,I3,5X,I4,3X,I3,3X,5(I2,1H-,I2,2X))
140 FORMAT (84X,   3HTLR,I3,2X,A3,I3,7X,F5.3,9X,F5.3)
    END
```

```
      SUBROUTINE OUTPUT
      DIMENSION RAN[illegible](100), R[illegible](100), CH[illegible](100), CL[illegible](100), [illegible]
     1(100), T[illegible](100), [illegible](100), CH[illegible](100), TEL[illegible](100), [illegible]
     2[illegible]), [illegible](5,5), [illegible]TLE(5,5), [illegible](5), [illegible](5), [illegible]
     3[illegible](100,20), MEAN(20), STDEV(20), [illegible]ADD(20)
      [illegible]
     1[illegible]
     2[illegible]
      COMMON /[illegible]/ [illegible]
     1,LUNP,L[illegible],[illegible],NEVENT,NTELAG,[illegible],TOTIND
      COMMON /[illegible]/ ITINT,IP
      [illegible]
      INTEGER [illegible],CL[illegible],TEL[illegible],T[illegible],[illegible]
     1TIND
      IF ([illegible]) 120,100,1[illegible]
  1[illegible] CONTINUE
  1[illegible] WRITE (LUNO,2[illegible])
C     [illegible] COMPUTE THE MEAN NUMBER OF NEW KNOWERS PER T[illegible]
C         PERIOD [illegible], AND THEN COMPUTE THE STANDARD [illegible]
C         [illegible] THE [illegible].
      Z[illegible]=FLOAT([illegible])
      DO 110 IT=1,NTI[illegible]
      MEAN(IT)=MEAN(IT)/ZN[illegible]
      STDEV(IT)=SQRT(STDEV(IT)/ZNRUNS-MEAN(IT)**2)
  110 WRITE (LUNO,2[illegible]) IT,MEAN(IT),STDEV(IT)
      GO TO 170
  1[illegible] WRITE (LUNO,240)
      DO 140 ICH=1,[illegible]
      DO 130 IN=1,TOTIND
  130 IF ([illegible](IN).EQ.ICH) NEVENT=NEVENT+1
  140 WRITE (LUNO,2[illegible]) ICH,NEVENT
      DO 160 ITEL=1,NTELAG
      NEVENT=0
      DO 150 IN=1,TOTIND
  150 IF (TEL[illegible](IN).EQ.TL[illegible](ITEL)) NEVENT=NEVENT+1
      [illegible](ITEL)
  160 WRITE (LUNO,2[illegible]) CL[illegible](IN),IN,CH[illegible](IN),NEVENT
  170 RETURN
C
  180 FORMAT (///,15X,11HTIME PERIOD,//15X,1[illegible](I4,[illegible]))
  1[illegible] FORMAT (/)
  2[illegible] FORMAT ([illegible]X,I[illegible],[illegible],I[illegible],[illegible]X,[illegible])
  210 FORMAT (1[illegible]X,1[illegible](1X,F6.2))
  2[illegible] FORMAT (1H1,15X,4HTIME,1[illegible]X,[illegible],/14X,6HPERIOD,[illegible]
     1 STD.DEV.//)
  2[illegible] FORMAT (1[illegible]X,I[illegible],[illegible]X,F[illegible].2)
```

```
240 FORMAT (///,1[illegible] V//,26X,A[illegible]X,[illegible],1
   1[illegible] [illegible])
[illegible] FORMAT (2[illegible]X,I[illegible],7X,I[illegible])
[illegible] FORMAT (2[illegible]X,I[illegible],1[illegible],I[illegible],1[illegible],I[illegible],2[illegible] 1,[illegible]X,I[illegible])
    END
```

```
      SUBROUTINE RANDOM (ILO,IUP,IREP,INTOT)
      DIMENSION RANIND(100), BOT(100), CHANGE(100), CLISUB(100), T[illegible]
     1(100), TLOWER(100), KNOWER(100), SUMTOT(100), TELSUB(100), N[illegible]
     2E), RKYCH(5,7), RKTLD(5,6), NXCOUN(6), KNOTLY(6), [illegible]
     3KND(100,30), MEAN(30), STDEV(30), SUMSQR(30), IRAND(10)
      COMMON /ARRAYS/ RANIND,BOT,CHANGE,CLISUB,TELLER,KNOWER,CL[illegible],T[illegible]
     1[illegible],NMEAN,NXCOUN,KNOTLY,[illegible],AVTOT,MEAN,[illegible],T[illegible]
     2RKYCH,RKTLD
      COMMON /VARIBL/ NOOBS,[illegible],NTI[illegible],IXCHAN,NCL[illegible],NBRINT,[illegible]
     1,LIMP,LI[illegible],NCURRV,NEVENT,ITELAG,[illegible],TOTINC
      COMMON /INDEX/ ITME,IP
      REAL MEAN
      INTEGER CHANGE,CLISUB,TELLER,TLOWER,[illegible],TELSUB,[illegible]ADD,RANIND,T
     1TIND
      DATA (IRAND=1352769213,[illegible],[illegible],3106[illegible],71[illegible]
     1,7556740060,[illegible],[illegible],[illegible],4706140469)
      DATA (MULTI=[illegible])
      NEXTAG=1
C          RANDOM NUMBER GENERATION SECTION
      DO 80 IN=1,INTOT
      IFLAG=1
   10 ITAG=NEXTAG
      IRAND(ITAG)=IRAND(ITAG)*MULTI
      IHOLD=IRAND(ITAG)/10**10
      IRAND(ITAG)=(IRAND(ITAG)-IHOLD*10**10)-IHOLD
      NEXTAG=IRAND(ITAG)-(IRAND(ITAG)/10)*10
      NEXTAG=NEXTAG+1
      IF (IFLAG.EQ.2) GO TO 70
C          DETERMINE POWER OF TEN FOR UPPER LIMIT
      DO 20 NTEN=1,10
      KK=IUP/10**NTEN
      IF (KK) 30,30,20
   20 CONTINUE
C          THE RANDOM NUMBER IS TRUNCATED TO THE [illegible] POWER OF TEN [illegible]
C           IN THE RANIND ARRAY [illegible]
   30 RANIND(IN)=IRAND(ITAG)/10**(10-NTEN)
C          TEST WHETHER RANIND IS OBTAINED WITH OR WITHOUT REPLACEMENT.
      IF (IN.EQ.1.OR.IREP.EQ.1) GO TO 50
      DO 40 KDUMMY=2,IN
      IF (RANIND(IN).EQ.RANIND(IN-1)) GO TO 10
   40 CONTINUE
C          TEST WHETHER RANIND IS BETWEEN LIMITS ILO AND IUP.
   50 IF (RANIND(IN).GE.ILO.AND.RANIND(IN).LE.IUP) GO TO 80
      GO TO 10
   60 IFLAG=2
      GO TO 10
```

```
C          THE NEXT TWO STATEMENTS [illegible]
   70 PRX (IN)=FLOAT(I[illegible])
      PROB(IN)=PRX (IN)/[illegible]
   [illegible] CONTINUE
      RETURN
      END
```