AN ADAPTIVE COMPUTER MODEL OF THE ADOPTION OF ELECTRICITY IN A VILLAGE COMMUNITY

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Abstract

The paper employs the Systemic Interaction Model (SYSTIM) approach to the modeling of social reality. Its specific focus is the process of evaluation of an innovation--electricity--by an Indian village community, in terms of the perceived cultural, social, political as well as economic and marketing benefits that are likely to arise for various types of socio-economic actors.

The path of commitment and final adoption of this innovation conforms to the well-known empirical adoption pattern observed for real-world villages.

1. INTRODUCTION

1.1. COMPUTER SIMULATION OF THE DIFFUSION AND ADOPTION OF TECHNOLOGY

At a time when a small segment of mankind is concerned with the sophisticated technology required to conquer outer space, the overwhelming majority of mankind is fighting the seemingly simple problem of wrestling but a few more bags of rice from a small parcel of land. This problem would appear to be even less formidable when it is recognized that the technology for the improvement in the productivity of land has been on hand at least for several decades. An example is found in electricity which not only provides a source of power for pumping water to the fields but also a means for lighting the huts of the villagers, and for powering radios, and other instruments of communication with the wider world.

While the desirability of adopting electricity may be evident to a Western observer, it is a far more complex and challenging problem to, say, an Indian village community whose set of shared experiences has not included the use of electricity, and for whom the economic sacrifice involved in its adoption has to be justified in terms of the total relevance to the economic, political, social, and cultural activities of the community. This perspective highlights the presence of a highly complex cognitive and risk taking process operating at the level of the individual and of a similarly complex group communications and decision process operating at the level of the group.

It is little wonder therefore, that the process of adoption of technology has attracted the attention not only of scholars from the whole spectrum of the social sciences, including a small but growing band of scholars who employ computer simulation as a means of theory development in this complex field. These simulations focus on the spatial or social spread of innovations in a village, region, or country.*

Many simulations of the diffusion and adoption

* See Appendix 1 for a summary of diffusion simulation studies.

of technology express the process of adoption in terms of the social system prevalent within a given village or region. Such a modeling of socio-economic factors is indeed necessary for an adequate representation of the process being modeled, but it may not be sufficient: Attitudinal and other behavioral factors influence the decision or commitment process in a hierarchical mode, together with processes of learning at the level of the individual and the group.

The process of adoption of electricity within an Indian village, therefore, is modeled not only in terms of the social structure of the village itself but also in terms of the decision process appropriate to different types of socio-economic actors. This decision process, which may be likened to a process of "creeping commitment," involves an evaluation of the new technology in terms of the total social system of the adopting group. In other words, electricity and its benefits and cost to the individual are evaluated in terms of the value system and the social structure prevalent, and also in terms of the political and economic interactions taking place in the village. The final cost to the adopter is compared to the sum of benefits accruing at all these levels of behavior. The decision to adopt a new technology therefore results not only from an evaluation of its economic benefits and economic costs, but also of its social contribution to the life of the community.

This approach to the modeling of transfer of technology processes -- termed the Systemic Interaction Approach -- is able to explain seemingly surprising phenomena observed in developing countries, where technology is either not adopted although its economic benefits would warrant an adoption, or where technology is adopted although its economic benefits would not seem to warrant such a course on the part of the adopting group.

This use of computer simulation is primarily relevant when the complexity of socio-economic processes is to be studied. From these theoretical insights into the dynamics of adoption processes it is only a further step to the formulation of policy and the planning of educational, community development, and economic projects. Although mathematical analytic models of the "contagion effect" involved in the process of innovation can be formulated for a simple system, the hierarchy of interactions, the lead-lag relations and complex feedback processes (operating within the model of the individual actor and also within the model of the total village community) make the use of the simulation approach highly desirable.

For purposes of theory development, the overall computer experiment can be considered successful if an exponential-type adoption curve results at the macro-level (i.e. the village community) from the complex interactions at the micro-level (i.e. the individuals). This exponential process of adoption is a familiar phenomenon verified in many empirical studies of the diffusion of innovations in both developed and developing countries, and at both the national (or regional) and the local level.

1.2. A SYSTEMS VIEW OF TECHNOLOGY TRANSFERS

Economic models generally are characterized by a one-process transformation of a set of inputs -- labor, capital, etc. -- into a set of outputs -- goods and services. In their simplest representation these models may be termed "black-box" models, as they relate the sum of inputs to the sum of outputs without specifying the nature of technology -- i.e., the mechanism that brings about the transformation of inputs into outputs. Such an approach is eminently rational as long as the transformation process is assumed as known and given, and as long as the understanding of this process may be considered an "engineering" and not an "economic" problem.

This approach to "technology" -- the undefined element in the black box model -- is clearly inadequate when:

(a) the level of output increases without a corresponding increase in inputs, i.e., in the case of technological change; and
(b) the process of economic development is to be explained, both as a process of the qualitative transformation of the human resource input, and also as the acquisition -- the diffusion and adoption -- of a new organizational or economic "technology."

In empirical studies of economic interactions -- exemplified, for example, by Leontief's input-output model of the American economy -- this problem becomes even more apparent: Relating inputs to outputs gives rise to technical coefficients of production for particular industries. However, changes in these coefficients can be assessed only ex-post-facto when social processes have run their course.

The thesis of this paper may be stated as follows:

(a) Changes in technology can only be understood and explained if the models of neo-classical economic theory are supplemented by models of the behavioral processes that give rise to the adoption or diffusion of innovations; and
(b) Because of the interaction of value norms and technological practice, cross-cultural adoptions of technology particularly require that these models must take into account not only communications from a change agent (who holds different values than the target population) but also an evaluative process over time, and at all levels of behavior, for all socio-economic types found in the target population.

Values are expressed in the form of decision rules applied by a particular socio-economic type in a given context -- the green, red, or yellow lights ("do, don't, maybe") of social action. For the representation of these types a general model of individual behavior organization, termed the Systemic Interaction Model (SYSTIM), was employed;** differences in attitudes, group norms, political activity, and economic and marketing roles are expressed by different values of the parameters of the model. These different socio-economic types were represented within an overall model of the village hierarchy and of the communications and decision processes that operate in the community.

This model is adaptive in the sense that
(a) its components -- the individual types of socio-economic actors -- are characterized by learning behavior at all levels of behavior and across all levels of behavior, and
(b) the overall system changes in response to the communications stimuli from the external environment (radio, community development officer, etc.) as well as from the internal environment (meeting of the village council, communications between elders, etc.).

In focusing on the socio-economic dimensions of the adopting group, the model abstracts from spatial or geographic dimensions of the diffusion process.*** As the theoretical structure of the model had to be expressed in the form of a feedback-control system's diagram for sake of clarity, it was convenient to use FORTRAN for machine simulation. The simulation mode was based on the occurrence of events placed at discrete points in time; accordingly, a discrete simulation mode was adopted to reflect the adaptive patterns within the simulated community and to express increasing levels of commitment to, and the final adoption of the new technology.

2. THE SYSTEMIC INTERACTION MODEL (SYSTIM)

2.1. A THEORY OF BEHAVIOR ORGANIZATION

Technology is defined for purposes of this model in a behavioral vein as the set of experiences which an individual or group brings to bear for the solution of a problem, or the conduct of an activity, in a given context. This set of experiences is viewed as the result of a learning process in a multi-level hierarchy where each level has an impact -- direct or indirect -- on every other level.

These levels of activity and of ensuing experiences are termed the cultural, social, political, economic, and marketing systems. Each level is treated as a subsystem of the total system, with inputs, outputs, and transfer functions pertaining to a given level, and appropriate linkages between these levels. Each level has a function -- denoted by the type of goal that is set -- and also an observable structure.

When viewing a total society or a group of individuals, the following functional and structural aspects may be mentioned briefly:
(a) The function of the cultural system (of a given society) is to motivate individuals towards the achievement of specific values or goals. Communications are the instrumental vehicles through which culture fulfills its function. (The process of acculturation or acquisition of new values is a learning process wherein an individual adapts to his human environment). Cultural learning may be viewed as a process of conditioning to group norms. The structure of the cultural system, which is the structure of values, is of two-fold nature: (1) in terms of the type of behavior they relate to, values are prohibiting, mandatory or permissive; (2) in terms of the time dimension to which they pertain, values may be of the very long run, long run, intermediate run, short run, or very short run nature. The "cultural" function of values, therefore, is to motivate individuals towards "very long run" behavior.
(b) The social system functions to provide the aggregate behavior or group roles required to reach the image of the "ideal state" embodied in cultural values (in the long run). The structure of the social system is given by the pattern of interrelationships between the members of the group.
(c) The function of the political system is to modify group goals and conflicts and for mobilizing groups for the attainment of intermediate-run goals. The structure of the political system is found in the government and party institutions regulating political life.
(d) The function of the economic system consists in the provision of goods and services for the want satisfaction of consumers in the short run (=resource allocation behavior). The structure of the economic system is found in production, distribution and consumption units.
(e) The function of the marketing system is the distribution of the surplus of goods and

** This model was formulated in Martin Pfaff, The Marketing Function and Economic Development: An Approach to a Systemic Decision Model (Ph.D. Dissertation, University of Pennsylvania, 1965), Philadelphia, Pa.: Marketing Science Institute, 1968.

*** For a treatment of the spatial dimension see Torsten Hägerstrand, The Propagation of Innovation Waves, Lund, Sweden: Royal University of Lund, (Lund Studies in Geography), 1952; and Georg Karlsson, Social Mechanisms: Studies in Sociological Theory, Uppsala, Sweden; Almquist and Wilksells, 1958.

services in the short run. The structure of the marketing system is found in the institutional link between producer, distributor (wholesale or retail) and consumer.****

Every member of the village community participates to some degree in every one of these behavior systems: As teacher, student or artist he operates primarily in the cultural system; as a member of a particular family or group he is participating in the social system; as member of a group engaged in cooperation competition, or conflict he takes part in the political system; and as farmer, craftsman, or vendor he constitutes part of the economic and marketing systems.

The linkage between the submodels of individual behavior and the overall model of the community is provided by the social position of an individual, which in turn, reflects various levels of commitment to the different levels of social activity: The teacher participates largely in the cultural system, the village headman in the political system, and the heads of household in the economic system, although each one, to various degrees, is involved also in the other levels of social action.

2.2. DEFINITION OF SYSTIM VARIABLES

In Figure I a feedback control diagram of the Systemic Interaction Model (SYSTIM) is shown. This version of SYSTIM represents the model of a type of socio-economic actor; while the basic structure is the same, different parameter values were chosen to represent different socio-economic types.

The variables shown in Figure 1 are defined as follows:

a. Q(i,it), (i=1,...6)

Q(1,it) denotes the degree of "suitability of value to high-activity behavior" -- or degree of modernity -- at a particular point in time or clock-instant, it.

Q(1,it) increases for most of the socio-economic types (to be described). Q(2,it) depicts the cultural behavior of individuals qua individuals (e.g. educational or artistic endeavors), while Q(3,it) denotes individual behavior as a member of a group (e.g. meetings of the village panchayat or assembly of elders, or discussions among male heads of households). Q(4,it) stands for political behavior, (e.g. conflict and conflict resolution within the village due to disagreements as to the desirability of introducing electricity into the village at the level of cost involved), Q(5, it) for economic behavior (e.g. the growing of rice and ancillary behavior), and Q(6, it) for marketing behavior (e.g. transportation of rice to the village bazaar or town market, or sale and purchase of other items).

The main relationships are depicted in the model consist of the link between economic "technology" and the various levels of superimposed learning processes. In the aggregative view the latter act as constraints to the scope of economic technology operating within the village community.

For i=1,...,4

(1) $Q(i+1,it+1) = .001 \times Q(i+1,it-1) + H_{i,i+1} \times H_{i+1,i} \times Q(i+1,it-2) + H_{i+2,i} \times Q(i+2,it-3) + Q(i,it) + H_{6,i} \times Q(6,it)$

Q(1,it) is given for all it. Therefore the final output is determined as

(2) $Q(6,it) = [.001 \times Q(6,it-1) + H_{56}] \times [H_{65} \times Q(6,it-2) + Q(5,it) + H_{65} \times Q(6,it)]$

b. H -- Transfer Functions

$H_{i,i+1}$, (i=1,...,5) denotes the forward transfer functions, while $H_{i+1,i}$ (i=1,...,5) denotes the feedback transfer functions for a particular levels of behavior.

$H_{i+2,i}$, (i=1,...,4) stands for the feedback transfer functions across two adjacent levels of behavior.

$H_{6,i}$ (i=1,...,4) and H_{65}, in turn, denote the "policy" feedback transfer functions which reflect the impact of policy measures instituted to influence the institutional environments of the economic-marketing process.

c. P_i -- Productivity Coefficients

(3) $P_i = Q_{i+1} / Q_i$ (i=1,...,5)

The ratio of output to input for a particular level measures the "productivity" --or degree of learning at the higher levels of behavior -- of the particular level.

d. T_i -- Time spent in activity, at each level (in hours)

e. PT_i -- Productivity-Time Ratio

(4) $PT_i = P_i / T_i = (Q_{i+1} / Q_i) / T_i$, (i=1,...,5)

This ratio measures the productivity of each system per unit of time.

f. F OUT -- Final Output

The final output of the total system is viewed from an economic point of view; in consequence,

****The function and structure of aggregate behavior systems is derived deductively from some axioms and theorems on individual and group behavior. For a statement of the main hypotheses and derivations, see M. Pfaff, op. cit., pp. 140-171.

both the time spent for economic and marketing activities which lead to economic income, are related to Q(6,it):

(5) $F\ OUT = (T_4+T_5)Q(6,it)$

g. $T_iQ(i+1, it)$ -- Output by Level of Behavior

(6) Cultural output: $C\ OUT=T_1Q(2,it)$

(7) Social output: $S\ OUT=T_2Q(3,it)$

(8) Political output: $P\ OUT=T_3Q(4,it)$

(9) Economic output: $E\ OUT=T_4Q(5,it)$

(10) Marketing output: $XMA\ OUT=T_5Q(6,it)$

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(5) Final output: $F\ OUT=(T_4+T_5)Q(6,it)$

h. CONS -- Consumption

Individuals consume 40% of F OUT, subject to a ceiling of 2 units in the hypothetical case. (e.g. if it is in "maunds" of rice, this ceiling will be in 2 mds of rice).

i. TAX -- tax levied on final output

(11) TAX = .08 F OUT

j. M OUT = XM OUT -- marketable output

(12) XM OUT=F OUT ÷ CONS - TAX

k. (M CONS = XM CONS) = .5 XM OUT

Consumption of goods obtained in exchange for half of the marketable output. (These goods consist in salt, materials, clothing, etc., which the villagers do not procure themselves).

l. SURP -- surplus

(13) SURP = .5 XM OUT

The relationship between the variables entering into the state model of individual behavior is expressed in the form of a flow chart, together with the group adoption process. (See Figure 2)

3. THE GROUP ADOPTION PROCESS

3.1. CHARACTERISTICS OF THE SIMULATED VILLAGE

The Indian village depicted in the hypothetical case is characterized by the following rather simplified social structure.

(a) A headman directs the affairs of the village; he is responsible for tax collection, settlement of disputes, etc. He is also head of one of the families.

(b) Nine elders act as village council, (panchayat, which means literally the "council of five", acting as a legislative body in the more routine affairs of the village. These 9 elders are also heads of families).

(c) Fifty heads of families (including the headman and the 9 elders) direct the affairs of the families.

(d) Fifty wives complement the fifty families.

(e) Each of the fifty families has 4 children.

(f) One local teacher serves the educational needs of the children.

As will be evident many sociological characteristics could be expressed within the hierarchical structure. However, as the focus of interest centers on the commitment process, these characteristics will be reflected in the response of the various groups to the sequence of communication events.

The main criterion for classification of the individuals is their degree of rigidity or flexibility to persuasive communications. A nominal scale is postulated that implies the presence of three decision rules:

(a) "Adopt new idea"

(b) "Adopt new idea only if it appears feasible"

(c) "Do not adopt new idea"

On the basis of this categorization the following eleven communication response types were formulated:

Type No	Designation	No of Individuals	Description
1	Headman	1	Flexible
2	Elder	4	Flexible
3	Elder	5	Rigid
4	Head of Household	20	Flexible
5	Head of Household	20	Rigid
6	Housewife	25	Flexible
7	Housewife	25	Rigid
8	Schoolteacher	1	Flexible
9	Children	100	Very flexible
10	Children	50	Flexible
11	Children	50	Rigid

The allocation of time in hours per day for the various communication response types (excluding children, who are not eligible to "vote" about the adoption of electricity) is as follows:

HOURS SPENT BY COMMUNICATION RESPONSE TYPE AT VARIOUS LEVELS

Level	System Design.	TypeNo. 1	2	3	4	5	6	7	8
1	Cultural	2	2	2	2	2	2	2	8
2	Social	4	4	3	4	4	4	4.5	4
3	Political	4	3	3	2	1	1	.5	1
4	Economic	5	5	5	6	6	6	6	2
5	Marketing	1	2	3	2	3	3	3	1
		16	16	16	16	16	16	16	16

3.2 DEFINITION OF TERMS PERTAINING TO THE GROUP ADOPTION PROCESS

The following additional variable were included to reflect the group adoption process:

(i) COST -- Per capita cost of introducing innovation (electricity) into the village, (excluding children)

(ii) M -- events

M_1 -- begin

M_2 -- Radio message regarding introduction of electricity is received on battery operated radio

M_3 -- Community development officer talks to group of villagers

M_4 -- Discussion among heads of household

M_5 -- Discussion among headman and elders

M_6 -- Community development officer talks to school teacher

M_7 -- Community development officer talks again to headman and elders, (who, in turn, talk to subgroups of villagers)

(iii) AB_i, (i=1,...,5) -- mean anticipated benefit accruing from adoption of innovation at a particular level of behavior. (This is a "response type mean" pertaining to each level of behavior organization)

For example, the introduction of electricity is valued very highly (in Rupee terms) by the school teacher for cultural activities -- the teaching of classes on cloudy days and the reading of books, etc. -- while the headman values it more highly for political and social activities.

Each individual expresses his anticipated benefit in terms of the opportunity cost of the innovation -- i.e. in terms of the amount of money he would be willing to give on the average to enjoy the benefit of electricity for a particular level activity. His decision to vote in favor of the innovation comes when the sum of such mean anticipated benefits exceeds the share of the total cost to be borne by him.

It must be noted, however, that his evaluation of such benefits changes after every communications event, depending upon (a) his communication-response type, and (b) the source of the communication.

RAB_i -- Represents actual anticipated benefit for a specific case drawn from a normal distribution.

(iv) N -- the number of individuals belonging to a particular response type.

(v) $S=\sum_{i=1}^{5} RAB_i$ -- the sum of anticipated benefits at all levels of behavior

(vi) V=Benefit-cost ratio -- $V=\frac{RAB_i}{COST}$

This benefit cost ratio reflects the individual's perception of the value versus the cost of the innovation to him as individual.

(vii) VOTE -- Votes

This variable reflects the number of individuals who favor the adoption.

As will be noted, the device of the "benefit cost ratio" and of "vote" mechanism makes possible a quantitative expression of the preferences of the group, without having to assume addidivity or comparability of utilities, thus avoiding other more difficult technical issues.

3.3. THE COMPUTER SIMULATION

The simulation of the group adoption process was carried out with the help of the General Electric 265 Time-Sharing System. It is also demonstrated how the process of stabilization of the states of individual behavior can be simulated for a particular communication-response type after an event has taken place.

The total cost of implementing the adoption of electricity in the village was assumed to be Rs. 3,500, so that the share of cost for each of the hundred voting members was Rs. 35. (See Stage 2 in the flow-chart in Figure 2). The states of individual behavior were assumed to be actually observed in their unstable condition during the first four clock instances after Event 1, "Begin," took place (Stages 3 & 4). With passage of time, a steady state is soon reached through the negative feedback control mechanism (Stages 12 through 22). The steady state of individual behavior gets slightly disturbed after the occurrence of every new event (Stage 5) as a result of the changes in the various transfer functions characterizing individual behavior at various levels. (Stages 9, 10, 11).

The steady state Q's, and also the productivity coefficients, consumption, and surplus for each of the eight communication-response types have been obtained explicitly for Event 1 (Stages 23 through 32), and similar state models can be obtained for the rest of the six events, if it is desired to observe the impact of each event on the final steady state of a particular response type.

In order to simulate the group adoption process, the hypothetical mean anticipated benefits at each of the five levels of behavior were read into the computer for each response type after an event took place. (Stage 33) The anticipated benefits were hypothesized to be normally distributed around their mean values with a standard deviation of 0.2 within a particular response type; this fact was simulated by picking up values of anticipated benefits at random, subject to normal distribution (Stages 25 through 38) The ratio of total benefit anticipated by a voting member in monetary units to his share of cost (Rs. 35) was then computed. (Stage 39) If this ratio was equal to or greater than one, the voting member would cast his vote in favor of adoption of electricity in the village. A total of seven events described in the previous section were simulated and votes in favor of adopting electricity were counted after each event. (Stages 40 through 42) It has been hypothesized that <u>the villagers had agreed among themselves to adopt electricity when, and if, at least half of the voting members cast their votes in favor of the same.</u> The simulation shows that this state was, in fact, reached after occurrence of event 5, even a larger number of voting members continuing to be favorable after events 6 and 7 took place.

4. CONCLUSIONS

The pilot run represents an overall experiment designed to verify the familiar exponential growth curve pattern of adoption described by empirical studies of the adoption of innovations. A failure of the simulation to provide a similar output pattern would provide a <u>prima-facie</u> evidence of the inadequacy of the theoretical structure reflected in the model.

Figure 3 indicates the event - time path of the votes in favor of adoption of electricity by the village community. It does conform to the empirically derived adoption curve. In this sense, the model fairs reasonably well in terms of <u>a test of face validity</u>: It reflects the complex link between individual behavior, organization, and group processes. Particularly, the role of individual evaluative processes -- reflected in the benefit-cost calculus of rational behavior as applied to all levels of social action -- in the overall dynamics of the group decision process is shown reasonably well. In this sense, the computer simulation served the end of theory development rather than of immediate policy formulation.

To take the step from theory development to policy formulation, empirical evidence on the micro-processes operating at the individual level and the macro-processes resulting at the group level are essential. Survey research methodology and psychometric and communications research techniques have been developed sufficiently to make such an undertaking in principle feasible. Moreover, a growing stock of insights and experiences with research into village communities is being accumulated. These considerations suggest that the need for empirical verification can be met by the in-depth study of a real-world village community.

APPENDIX I: A SUMMARY OF DIFFUSION SIMULATION STUDIES*

	Researcher	Innovation Studied	Locale of the Study	Objective of the Research
1.	Hägerstrand[a]	Subsidized pasture improvement	Sweden	Trace spatial diffusion and social diffusion with computer simulation
2.	Karlsson[b]	A hypothetical new idea	None	Develop a non-machine simulation of the diffusion of new ideas with synthetic data
3.	Deutschmann[c]	A hypothetical farm innovation	Latin American village	Construct a preliminary model of diffusion illustrated with synthetic data
4.	Pitts[d]	Hand tractors	Japan	Geographical diffusion within a nation
5.	Silvernail[e]	Blister rust in white pine trees	Northeastern U. S.	Geographical diffusion of a disease
6.	Tiedemann and Van Doren[f]	Hybrid seed corn	Story County, Iowa	Geographical diffusion of hybrid corn from seed dealers to farmers
7.	Bowden[g]	Irrigation wells	Colorado	Geographical diffusion to predict future use of water resources
8.	Gould[h]	Cooperatives	East Africa	Social and geographical diffusion leading to modernization
9.	Wolpert[i]	Tractors and automatic self-binders	Sweden	Regional simulation incorporating a two-step flow of communication
10.	Yuill[j]	Hypothetical innovations	None	Effects of barriers on spatial diffusion of ideas utilizing synthetic data
11.	Hägerstrand[k]	Such innovations as a church movement, public bath houses, and dairy cattle vaccination	Sweden	Spatial spread of innovations
12.	Brown[l]	Artificial dairy cattle insemination and television sets	Sweden	Spatial spread of innovations

*Source: J. David Stanfield, Nan Lin, and Everett Rogers, "Computer Simulation of Innovation Diffusion in a Peasant Village", (Mimeographed), Department of Communications, Michigan State University, East Lansing, Michigan.

a. Torsten Hägerstrand, The Propagation of Innovation Waves, Lund, Sweden: Royal University of Lund, 1952.

b. Georg Karlsson, Social Mechanisms: Studies in Sociological Theory, Uppsala, Sweden: Almquist and Wilksells (and New York: Free Press of Glencoe), 1958.

c. Paul J. Deutschmann, "A Machine Simulation of Information Diffusion in a Small Community", San Jose, Costa Rica: Programa Interamericano de Informacion Popular, Mineo Report, 1962.

d. Forrest R. Pitts, "Problems in Computer Simulation of Diffusion", Regional Science Association Papers, 2 (1962), n.p.

e. Richard Silvernail, "Simulation of the Spread of Blister Rust in White Pine Forests", Paper presented at the Working Conference on Spatial Simulation Systems, University of Pittsburgh, 1964.

f. Clifford E. Tiedemann and Carlton S. Van Doren, The Diffusion of Hybrid Seed Corn in Iowa: A Spatial Simulation Model, East Lansing: Michigan State University, Institute of Community Development and Services, Technical Bulletin B-44, 1964.

g. Leonard W. Bowden, Diffusion of the Decision to Irrigate: Simulation of the Spread of a New Resource Management Practice in the Colorado Northern High Plains, Chicago: University of Chicago, Department of Geography, Research Paper 97, 1965.

h. Peter Gould, "A Note on Research into the Diffusion of Development", Journal of Modern African Studies, 2 (March, 1964), pp. 123-125.

i. Julian Wolpert, "A Regional Simulation Model of Information Diffusion", Public Opinion Quarterly 30(Winter, 1967),pp. 597-608.

j. Robert S. Yuill, A Simulation Study of Barrier Effects in Spatial Diffusion Problems, Evanston: Northwestern University, Department of Geography, Technical Report 1, 1964.

k. Op. cit., 1965

l. Lawrence A. Brown, Models for Spatial Diffusion Simulation, Evanston: Northwestern University, Ph.D. Thesis, 1966.

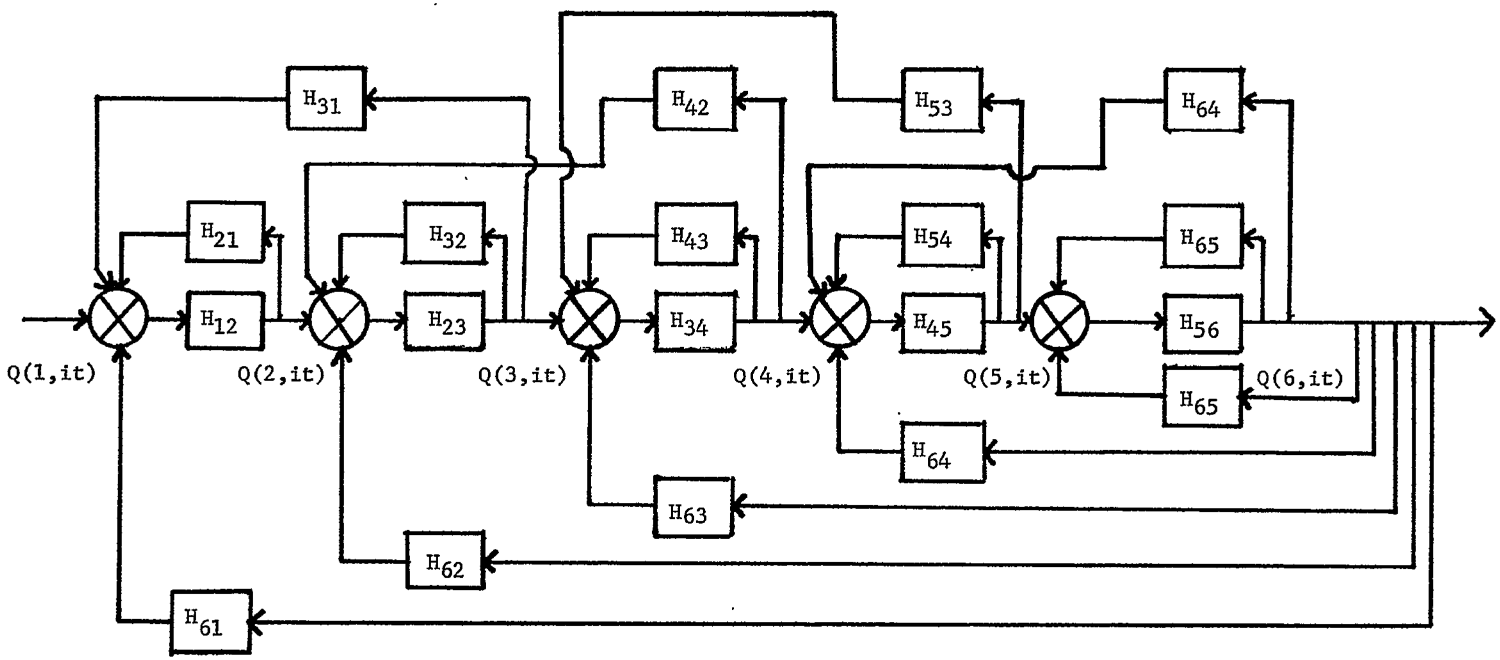
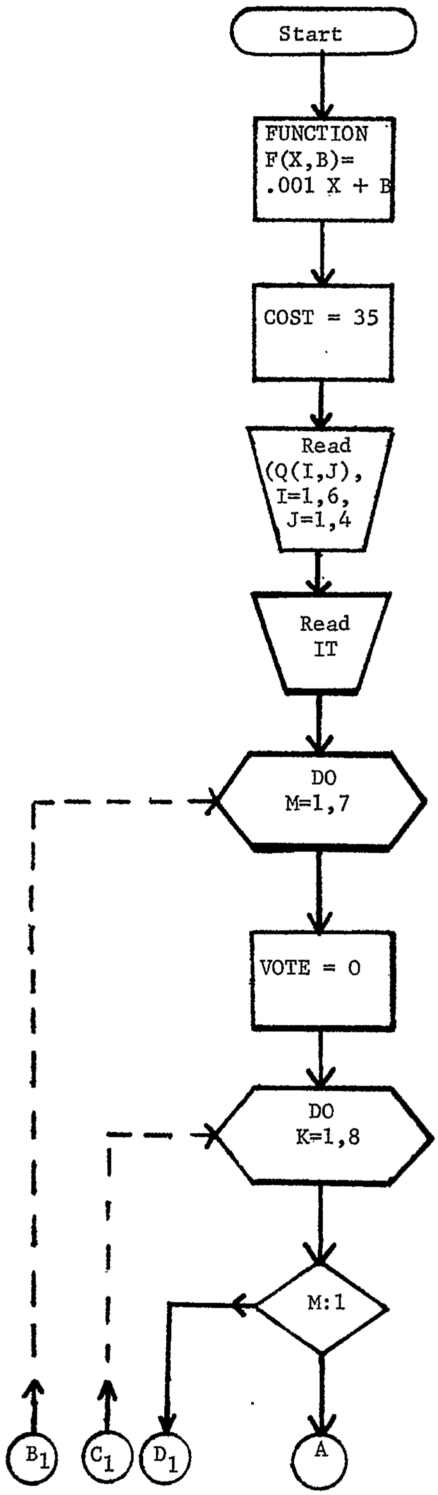
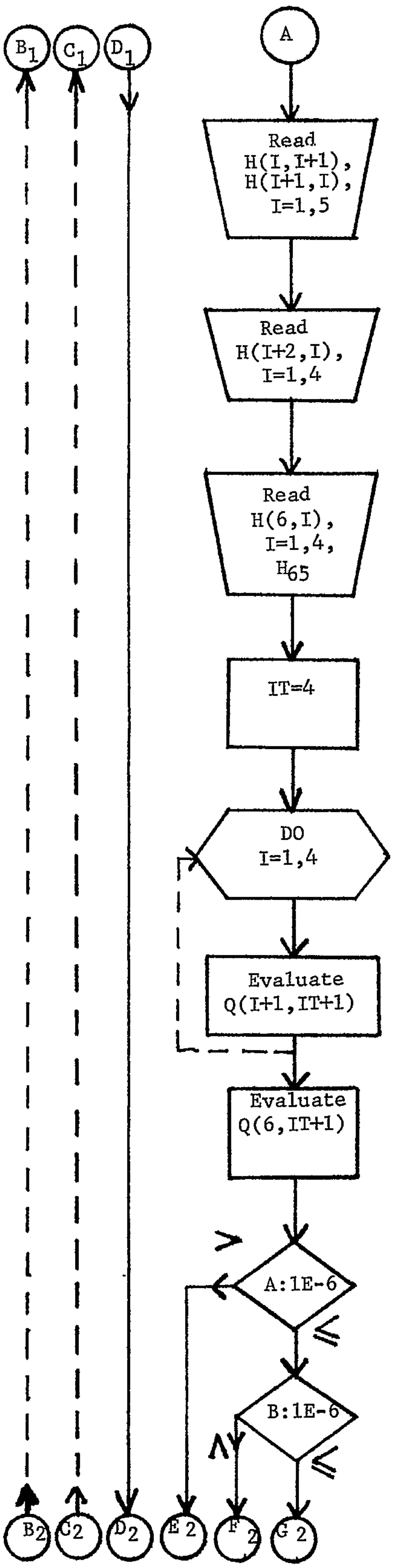


FIGURE 1: FEEDBACK CONTROL DIAGRAM OF THE SYSTEMIC INTERACTION MODEL

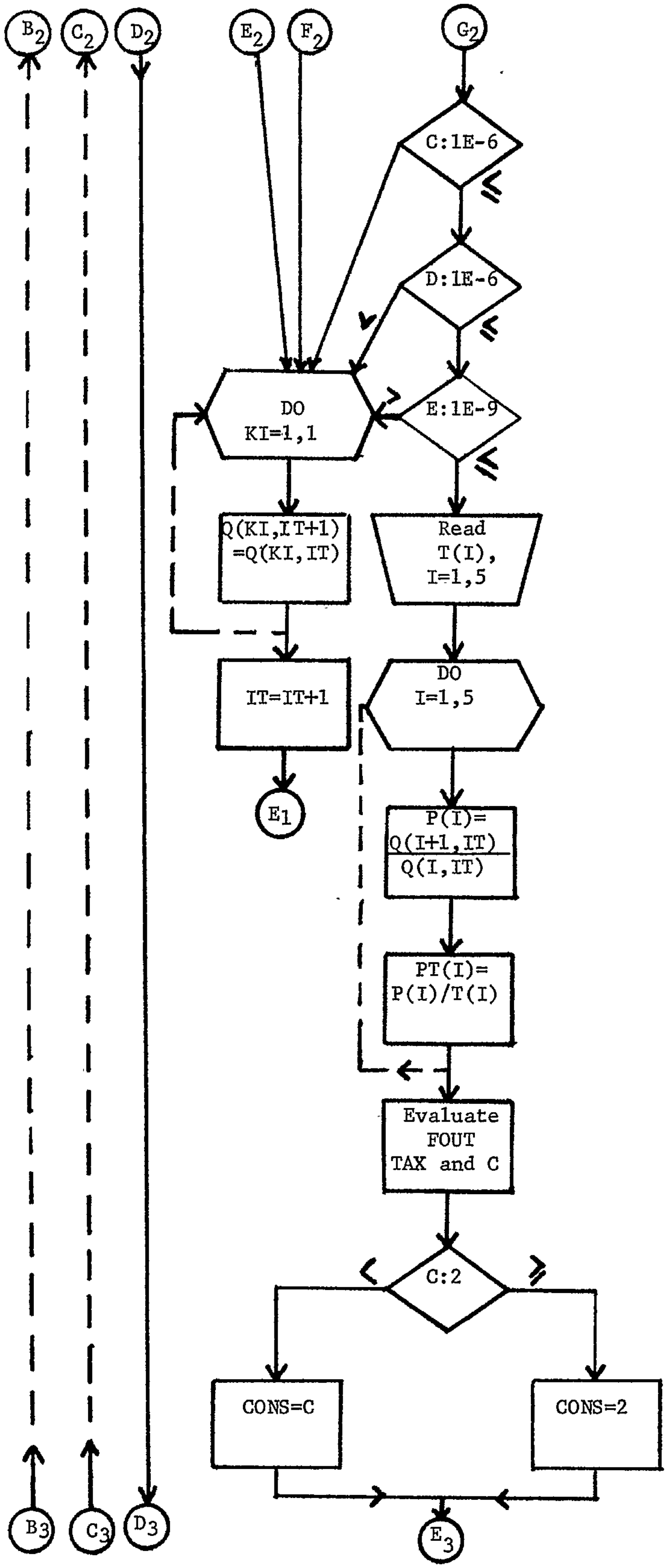
FIGURE 2: FLOW CHART



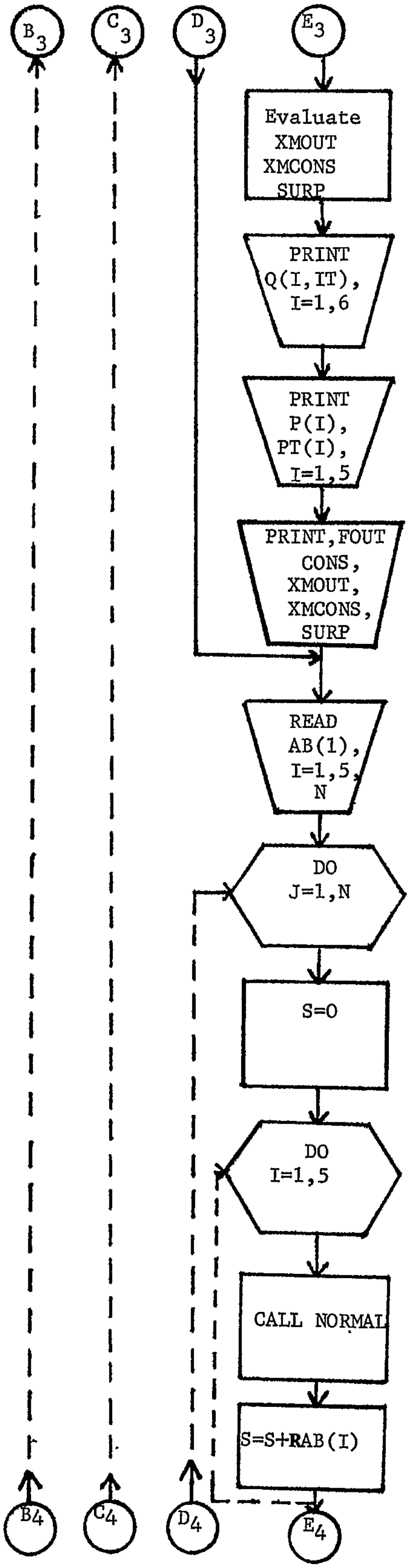
Stage	Explanatory Notes
(1)	This function is used in stages (13) & (14) below in the context of simulating the internal learning mechanism.
(2)	Share of cost for each voting member = Rs. 35.
(3)	Observed (unstable) states of individual behavior at the first four clock-instants after Event 1, "Begin" took place.
(4)	
(5)	No. of events = 7
(6)	Initialization of votes at the beginning of each event.
(7)	No. of response-type-eligible for voting = E
(8)	State model of the eight response-types shown explicitly for the first Event.



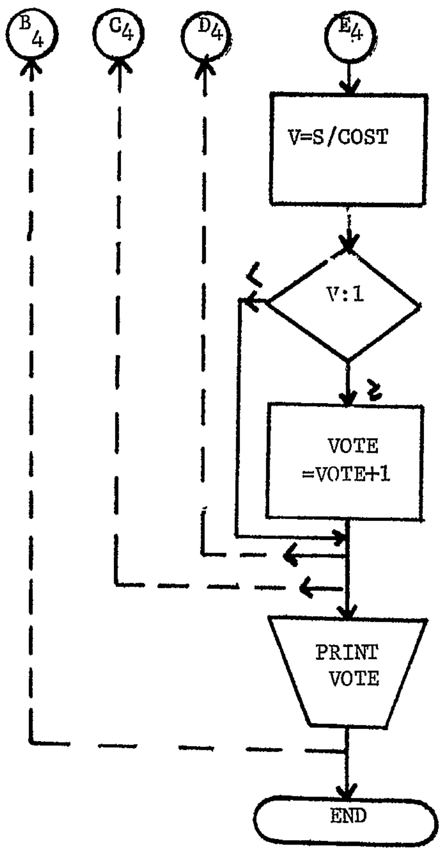
Stage	Explanatory Notes
(9)	Intra-level forward and feedback transfer functions.
(10)	Feedback transfer functions from adjacent levels.
(11)	"Policy" transfer functions from the output, Q_6, of the last level.
(12)	Q(I+1,IT+1)= F(Q(I+1,IT-1),H(I,I+1)), *[H(I+1,I) * Q(I+1,IT-2), +H(I+2,I) * Q(I+2,IT-3), +Q(I,IT) +H(6,I) * Q(6,IT)]
(13)	
(14)	Q(6,IT+1)= F(Q(6,IT-1, H(5,6)) *[H(6,5) * Q(6,1T-2) + Q(5,IT) + H(6,5)+Q(6,IT)]
(15)	A≡ |Q(6,1T) - Q(6,1T+1)|
(16)	B ≡ |Q(5,1T)-Q(5,1T+1)|



Stage	Explanatory Notes
(17)	C ≡ |Q(4,1T) - Q(4,1T+1)|
(18)	D ≡ |Q(3,1T)-Q(3,1T+1)|
(19), (22)	E ≡ |Q(2,1T) - Q(2,1T+1)|
(20), (23)	Time spent in activity at each of the five levels.
(21), (24)	
(25)	Productivity Coefficients
(26)	Productivity-Time Ratios
(27)	FOUT=(T(4) + T(5)) * Q(6) TAX = .08 * FOUT C = .4 * FOUT
(28)	Consumption

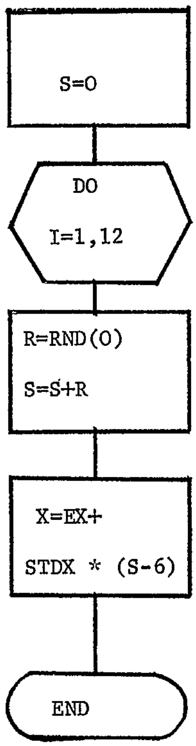


Stage	Explanatory Notes
(29)	SMOUT=FOUT-CONS-TAX XMCONS=0.5 * XMOUT SURP = 0.5 * XMOUT
(30)	
(31)	
(32)	
(33)	Anticipated benefits in monetary units at each of the five levels.
(34)	N=No. of individuals belonging to a response-type.
(35)	Initialization of sum, S, of randomized anticipated benefits, RAB(I),I=1,5
(36)	
(37)	Anticipated benefits assumed to have a normal distribution. NORMAL (AB(I),.2,RAB(I))
(38)	



Stage	Explanatory Notes
(39)	
(40)	
(41)	Vote cast in favor of introducing the innovation if V≥1.
(42)	

SUBROUTINE NORMAL (EX,STDX,X)



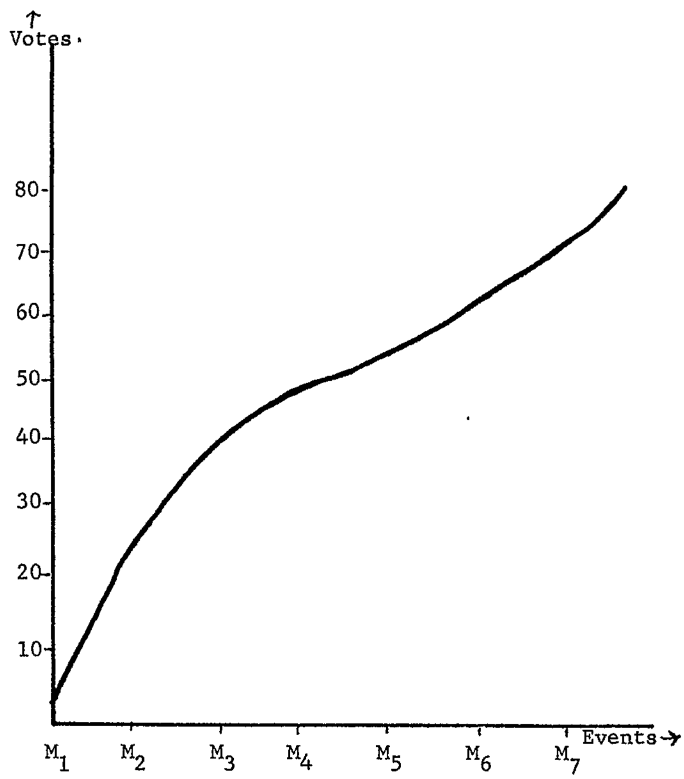


FIGURE 3: PATH OF GROUP ADOPTION PROCESS