A SYSTEM SIMULATION STUDY OF DYNAMIC SOCIAL CHANGE

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SOCIAL SYSTEMS MODELS

The major concern of sociology in the past has been the development of a set of techniques or methods useful in identifying and defining sociological concepts. The effort has been directed toward the development of research methods, the establishment of theories, and the gathering of empirical data. The same sequence of concerns or activities could be traced in the development of other sciences.

In the development of the physical sciences, similar early concerns and activities could be observed. One of the features of a science in the early development stages is a concern for establishing methods and gathering a body of data. The empirical data are often unrelated and little effort is expended to "systematize" this information. At later stages of development the science begins to focus attention upon seemingly unrelated and diverse data in an effort to discern interrelations and interactions. An overall scheme or unifying "system" is proposed to explain the multitude of seemingly diverse points of data. This structuring of previously unrelated information often leads to considerable advances in knowledge and understanding--often at the expense of extensive discussion and rethinking of past positions. The resulting system or theory is then referred to as a model.

The three major types of models receiving consideration in current sociology are the mechanical, organic, and process models.[1] The mechanical model is often referred to as "social physics" in that it utilizes methods, concepts, and assumptions from the physical sciences in a directly analogous manner. Terms such as "pressure," "attraction," "spatial coordinates," and "equilibrium" are representative of the wide reliance on physical concepts. Sociologists who employ the mechanical model, or its close conceptual relatives, include Homans, Parsons, Sorokin, and Lewin, as well as many others.[2]

The organic model, or conceptual framework, is based upon the concept that Spencer described as the "mutual dependence of parts" exhibited by the society or social system.[3] The sociologists who employ this model in their analysis seek out the interrelations, interactions, and interdependences of the entities within the social system they are examining. The entities considered vary in size and scope from individual to family to large scale organizations such as ethnic groups. The functionalistic approach in modern sociology, such as presented by Durkheim, Merton and others, is a refinement of the organic model.

The third major model type is the process model as presented by American sociologists of the "Chicago school" in the early twentieth century.[4] The process model "focuses on the actions and interactions of the components" of the social system.[5] The basic premise of the process model is that the structure is continuously undergoing change and attention should be directed toward this continuing change or process. The structure is a reflection of the changes occurring and not the cause of the changes.

From the above discussion and further readings of current sociological effort, it becomes apparent that there is no pure model or concept being applied. All current work, even that of an individual, reflects a blending of models, concepts and theories. Further support for the above contention can be seen in the current interest in the sciences (both physical and social) in the general systems theory.

General systems theory or the general systems approach deals with complex sets of entities that are causally related, or interact, in a relatively well defined manner over time. The length of time of the interaction may vary from system to system, but the interactions are assumed known and relatively stable during this time. Within the "systems approach" the three major social models discussed earlier may be combined and dealt with in an overall "systems" model. The application of the general systems approach to sociological investigation can be seen in current work.[6,7,8]

SYSTEMS MODELING AND SIMULATION

This paper will apply the concepts of general systems theory and systems modeling-simulation to an initial study of social group interaction. The social groups or organizations to be considered are those relating to the "civil rights movement" within American society. It is necessary, at an initial stage, to deal with higher level, macro structure, relations and interactions. This paper will show that it is possible, at a macro level, to examine the dynamic nature of the interactions between social groups and categories such as the civil rights movement, legislative bodies, and the general non-civil rights society. The method that is used to accomplish this examination of "key" social system parameters and interactions is that of systems modeling and simulation.

A consideration of the civil rights movement and its interface with the political-legislative groups of American society shows that this "system" exhibits the following four major characteristics of a goal-seeking complex system:[9]

(1) Its characteristic features depend on certain internal parameters and values remaining within certain limits.

(2) Its structure has developed a selective sensitivity to external changes relating to its values.

(3) It possesses mechanisms able to sense deviation in behavior or condition from its goal or values.

(4) It is able to respond to sensed deviation so as to reduce the deviation (negative feedback) or increase the deviation (positive feedback).

In addition, a considerable amount of work has been accomplished in the study of such complex feedback control systems.[10,11]

A SOCIAL-LEGISLATIVE SYSTEM MODEL

The model of the civil rights/political-legislative system is based upon a selection of relevant relations and interactions which exist in the real social system being considered. This process of abstraction or system definition is required to arrive at any model. Paradoxically, there is no theory or method available to guide this abstraction process in such a manner that a useful, unbiased model results! For this reason, the assumptions and simplifications that underlie the model are explicitly stated and open to comment. The general assumptions are:

(1) There are two groups (X and Y) within American society. The groups have measurably different levels of social acceptance, economic and educational opportunity, legal standing, mobility, and many other factors. The members of either group are capable of perceiving the different levels and arriving at a subjective feeling of their position in relation to the other group. This will be termed the level of "Social Expectation and Satisfaction."

(2) Group Y will be considered to be the "inferior" or "deprived" group in that it has a lower level of Social Expectation and Satisfaction (SES). Group X, therefore, is the "superior" group--has a higher SES level.

(3) The SES level of Group X or Y may vary over time due to many considerations. For this study, Group X will remain constant and Group Y's level will change only in response to factors included in the model.

(4) Group X is not basically opposed to Group Y's seeking or achieving equality--equal rating of SES index. However, Group X is complacent in that it will naturally prefer to leave things as they are (maintain status quo) unless forced to do otherwise. Group Y must initiate change.

(5) One method of achieving equality is through political, governmental influence, and new legislation. This will be considered as the only method within this model.

(6) Group X is more numerous than Group Y--has more voters. Therefore, the legislators (government leaders) are more likely to act in accordance with what they <u>believe</u> Group X desires.

(7) Government leaders or legislators have a four year term of office.

(8) During the last quarter of their term (1 year) the legislators seek to avoid controversy in executing their office. Since there are more Group X voters, the legislators act as they believe Group X desires, and decrease the amount of pressure on "equality" legislation or activities affecting the Group Y level of SES.

(9) Upon election (or re-election) to office, the legislators attempt to appease Group Y voters. This causes them to increase pressure on "equality" legislation and activities during the first quarter (1st year) of their term.

(10) During the rest of the term, the legislators maintain the average or normal level of pressure on the "equality" legislation and activities (middle two years).

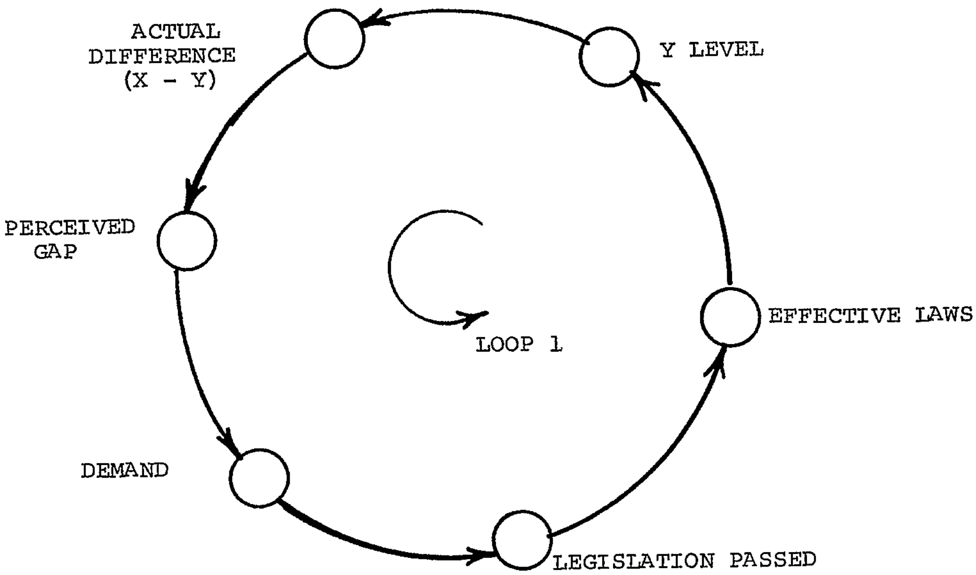
Further simplifying assumptions are as follows:

(1) Delay in time for new "equality" legislation or activities to become effective is three years.

(2) Group Y will demand new legislation or influencing activities as some portion or percentage of the <u>perceived</u> difference in levels (X-Y) each year.

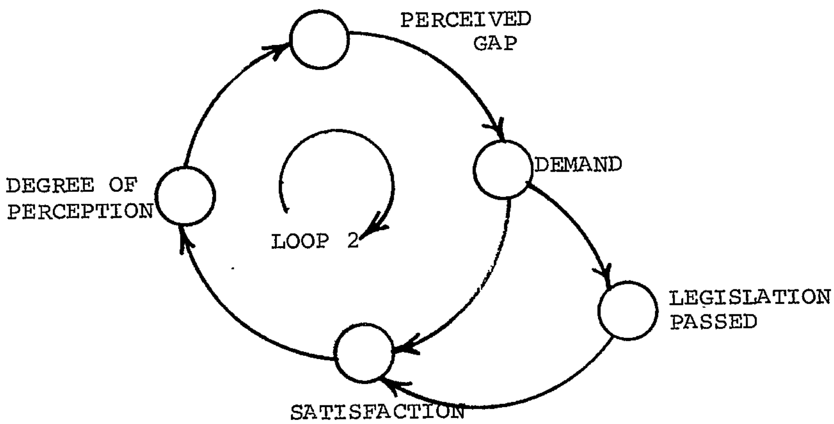
(3) Group Y's perception of the actual difference (gap) varies over time due to satisfaction or dissatisfaction with the rate of change received, actual difference in levels, legislative response, and other influencing factors.

Figure 1a



DEMAND - RESPONSE - LEVEL LOOP

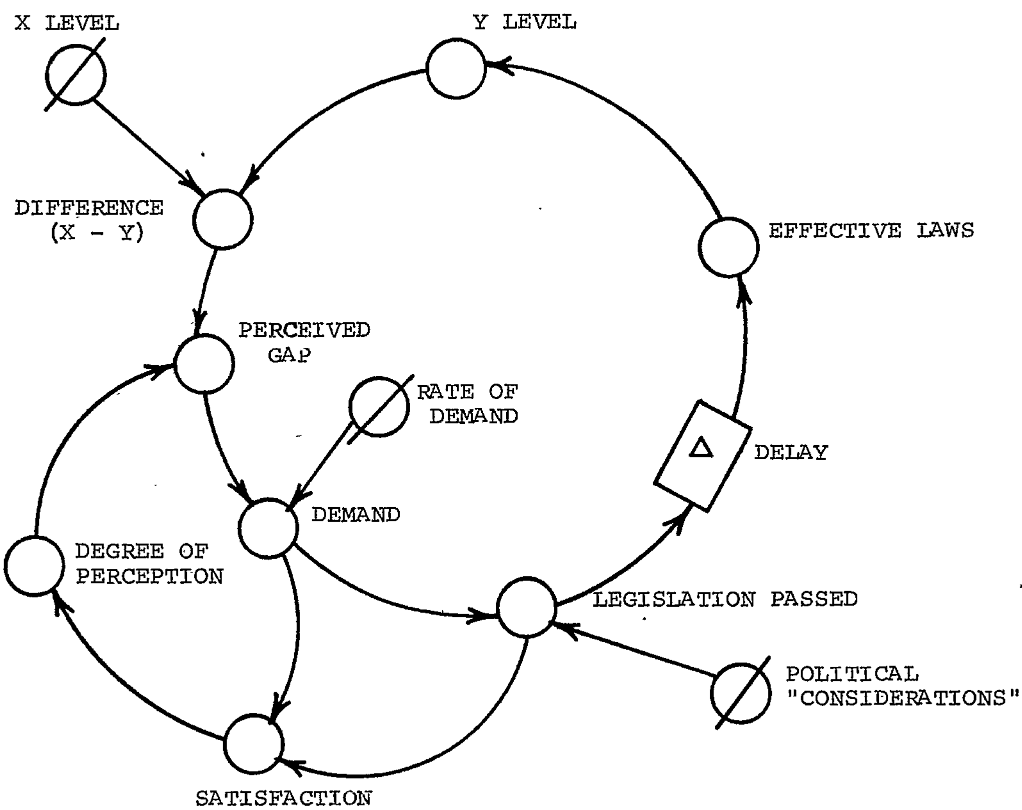
Figure 1b



PERCEPTION - DEMAND - SATISFACTION LOOP

Figure 2

OVERALL SYSTEM CAUSAL DIAGRAM



Combined Loop 1 and 2 plus exogenous inputs.

(4) In the mid-term years (second and third of term), ten laws are passed. Twelve laws are passed in the first year of each term and only eight are passed in the fourth or last year. This assumption is an admittedly arbitrary means of implementing the general assumptions pertaining to legislative response to political considerations as set down in (8) through (10) above.

(5) Each new law or revision when put into effect cuts the actual gap by 1/10th of the demanded new legislation.

(6) Group Y expects 10 laws to be passed per year. If less than 10 laws are passed in any year, the Group Y perception of the actual gap increases. In years when more than 10 laws are passed, the perception of the gap is decreased by the same amount it was increased in the years when less than 10 laws were passed. No change in perception of gap occurs when the expected number of laws are passed.

The structure of the model as presented by the assumptions given above is shown in Figures 1a, 1b, and 2. The figures are causal diagrams depicting the interrelationships of the entities presented in the stated assumptions. Figure 2 presents the total causal diagram of the model as used in the system simulation and analysis. Variables and constants external to the system (exogenous) and the delay considered are shown.

SYSTEM SIMULATION AND RESULTS

The model, as represented in Figure 2, was translated to a FORTRAN program and run on a GE 415 computer. The parameters utilized in the various simulation runs were:

(1) Group X and Y levels were initially set at 80 and 40 units respectively. This is an assumption that Y is one-half relative to the level of Group X.

(2) Delay in time for legislation to become effective was run for cases of three and five years respectively.

(3) The base level of Group Y perception of the gap was varied from 0.80 to 1.20 in steps of 0.20. A base level of perception of 0.80 could be interpreted as "optimistic" relative to the "pessimistic" 1.20 value.

(4) The variation in perception about the base perception level (above) was tested at 0.20 and 0.40 respectively. The variation of 0.20 can be termed "calm" relative to the "excitable" variation of 0.40. An "excitable" "optimist" would have a range in perception from 0.40 (0.80-0.40) to 1.20 (0.80+0.40) of the actual gap (X-Y).

(5) The demand rate was varied over a range of 0.05 to 0.50 of the perceived gap. A higher rate of demand (0.50) may be considered "radical" relative to a lower demand rate (0.10).

The model simulates the system behavior over 25 years in half-year increments. Output from the model is presented as a graph of the X and Y levels of Social Expectation Satisfaction over time and the level of Demand for Legislation (by Group Y) and the Legislation passed during that period of time. The scale for the X and Y levels ranges from 0 to 100 units, and the D (demand) for L (legislation) scale is from 0 to 10 units. The units are in terms of the Social Expectation and Satisfaction rating where Group X was arbitrarily set at 80 units.

The model was used to explore the effects of parameter variation on the following:

(1) The relation between Group Y's demand rate for legislation and the rate of "equality" achievement as shown by the relative levels of Group X and Y SES over time.

(2) The effect of differing levels of gap perception by Group Y--"optimism" versus "pessimism."

(3) The effect of variation in the gap perception, on the part of Group Y, due to satisfaction and dissatisfaction.

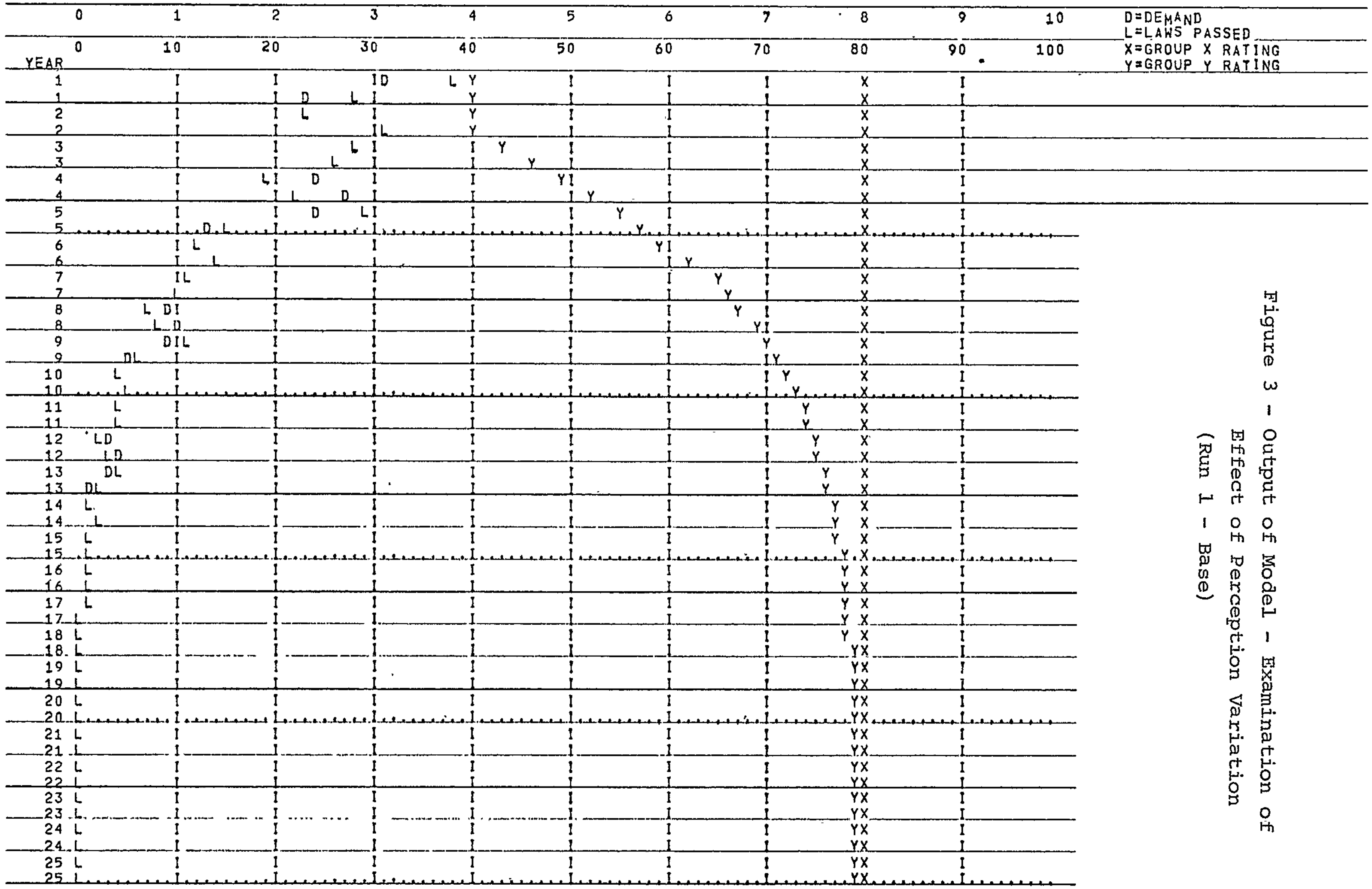
(4) Indication of social system stress through the relative levels (peaks and duration) of the demand for legislation and the legislative activity.

(5) The effect of delay, lag between legislation passage and its becoming effective, on system behavior.

It should be noted, as an assumption, that the "goal" of the social system being evaluated and modeled herein is to achieve "equality" within a "reasonable" period of time with minimal stress on the overall system. In the terms of this model, the system's objective is to have the Group X and Y levels become equal over time, with minimal variation in the levels of Demand and Legislation.

The results of model simulation enable the following general conclusions to be made:

(1) The higher the level of demand for legislation by Group Y, the sooner the attainment of equality.



VARIABLES - DEMAND = 10, PERCENT OF PERCEIVED GAP
PERCEPTION LEVEL = 80. PERCENT OF ACTUAL GAP
VARIATION IN PERCEPTION = 20. PERCENT

Figure 3 - Output of Model - Examination of Effect of Perception Variation (Run 1 - Base)

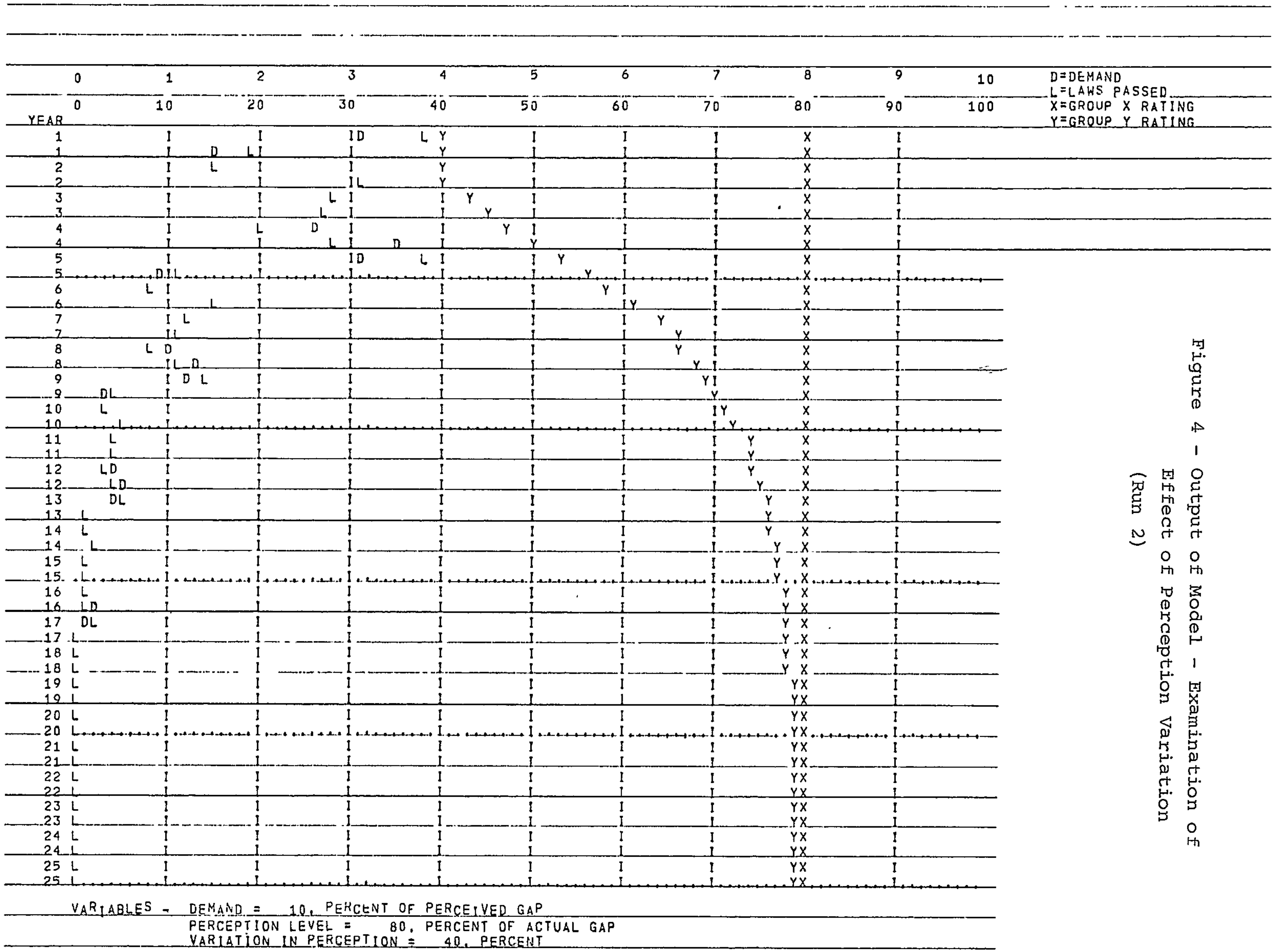


Figure 4 - Output of Model - Examination of Effect of Perception Variation (Run 2)

(2) The higher the demand, the greater the system "stress" indicated by demand and legislative levels.

(3) The higher the level of perception (the more "pessimistic") of Group Y, the higher the "stress" level and the sooner the attainment of "equality."

(4) The greater the variation in perception ("calm" versus "excitable") the higher the "stress" levels, with no decrease in the time to attain "equality." In other words, higher variation in perception gives no improvement in the system performance. In fact, the time to equality is slightly higher in the cases of greater variation. This is due to the dampening effect of excessive "optimism" lessening the demand level.

(5) The longer the time for legislation to become effective (5 versus 3 years delay), the sooner "equality" is achieved. This is a surprising result which is caused by the fact that the longer delay causes the demand for legislation to remain higher over a longer period. The net effect is the achievement of equality sooner.

(6) The system is capable of exhibiting oscillatory behavior for certain parameter values. The "extreme" cases of oscillation (demand of 0.50) are damped and would reach the "goal" of equality for the X and Y levels. However, it would be safe to assume that such "extreme" behavior would be prevented by factors not considered in this model.

Figures 3 and 4 present the model output from two separate simulation runs. The only change in parameter values between the two runs are in the degree of perception variation--20 versus 40 percent at a perception level of 80 percent. As discussed above, the output indicates increased social system stress (higher demand--D) with no improvement in shortening the time to "equality."

The overall results of the system simulation presented above are seen to represent a reasonable system behavior. The only result that was not "intuitively" obvious was the effect of legislative delay on system response--item (5) above. As the system being considered develops in complexity beyond this initial stage, its behavior will cease to be intuitively obvious, and the system model will become increasingly useful in aiding analysis of the system.[12,13]

The next step in this model's development would be to introduce Group X behavior in an active fashion. It could be assumed that Group X would also perceive the gap in the level between X and Y. The perception of X, being the "superior" group, would most likely be "optimistic." That is, Group X would perceive the gap as smaller than it truly is. In addition, Group X compares its perception of the gap to the demand that Group Y is making for legislation. If Group X feels that the demand is excessive, then, it is assumed, they will react so as to reduce the legislation being passed to a level that Group X finds "acceptable." In terms of the model, the following assumptions are included:

(1) Group X perceived the gap as 50 percent of its actual size and believes a demand of ten percent is acceptable.

(2) If the Group Y demand exceeds Group X's "allowed" demand by a ratio of 2/1, then Group X will cause the legislators to limit the laws passed to no more than 10 percent of Group X's perception of the gap.

Figure 5 shows the causal diagram resulting from these additional considerations in the model.

The results of simulation runs with the above changes included show the "performance" of the system is changed appreciably--the time to achieve equality is lengthened with no beneficial reduction in "stress" indicators. Figure 6 shows the effect of X-interaction on the system's behavior. The model as now structured is beginning to exhibit behavior more closely resembling the real-world social system of concern. It is still a macro-level model. However, it is approaching the realm in which human intuition becomes inadequate and often erroneous.

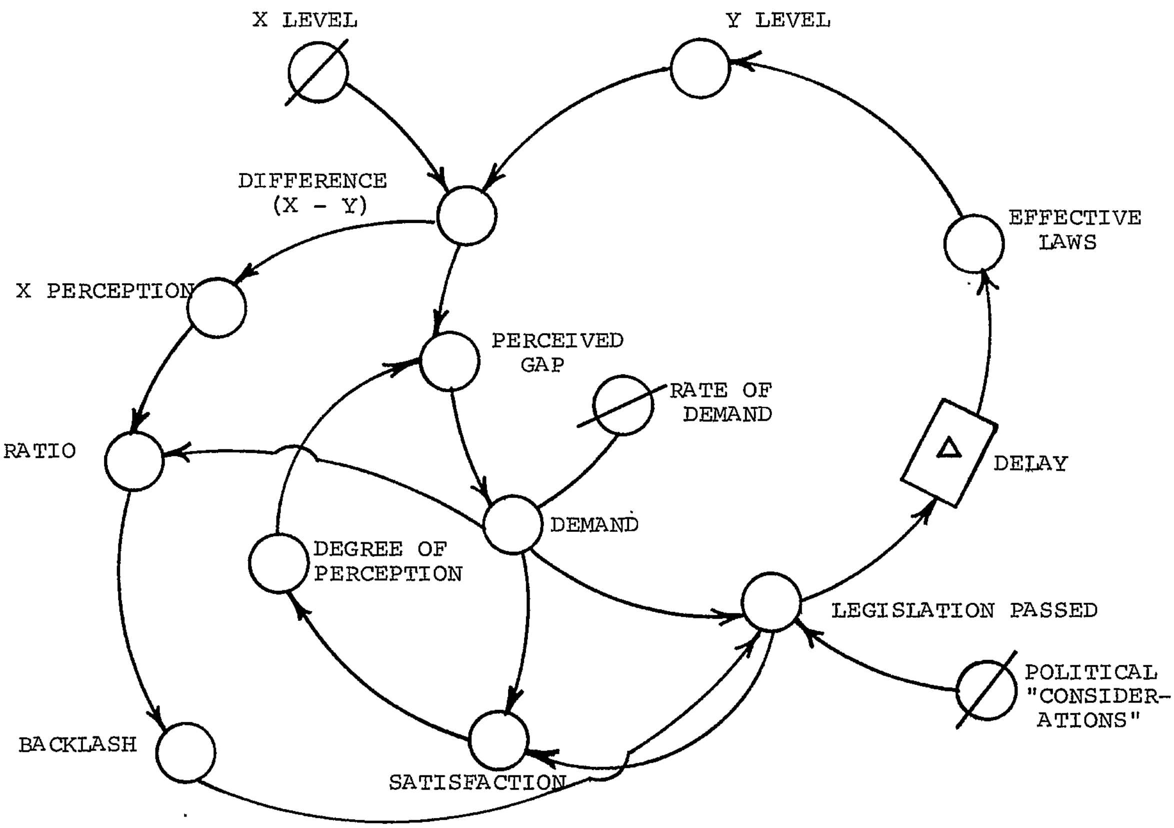
FORTRAN VERSUS DYNAMO

The social system model presented in this paper was also simulated using DYNAMO II in order to compare this language with FORTRAN for modeling use.[14] It is apparent that the simulation language used, once the system is described in causal diagram form, should have no influence on the dynamic behavior of the model. That is, the differences between languages should be only those of facility of use and ease of output realization. The simulation language should not force the user to compromise in his representation of the system under study.

Figures 7 and 8 show the output from the model simulation using DYNAMO. Figure 7 is run for the same parameter values as the run presented previously in Figure 3. Figure 8 is the DYNAMO run with the same parameter values as used in the case of X-Group Interaction, Figure 6. Comparison of the FORTRAN runs of Figure 3 and 6 with the DYNAMO runs of Figures 7 and 8 respectively show the simulation results of the model in both FORTRAN and DYNAMO are similar in all major aspects. The few differences noted are caused by the manner in which initial values are determined. In the FORTRAN model they were arbitrarily selected while the DYNAMO compiler computes initial values using an

Figure 5

SYSTEM CAUSAL DIAGRAM OF X-INTERACTION



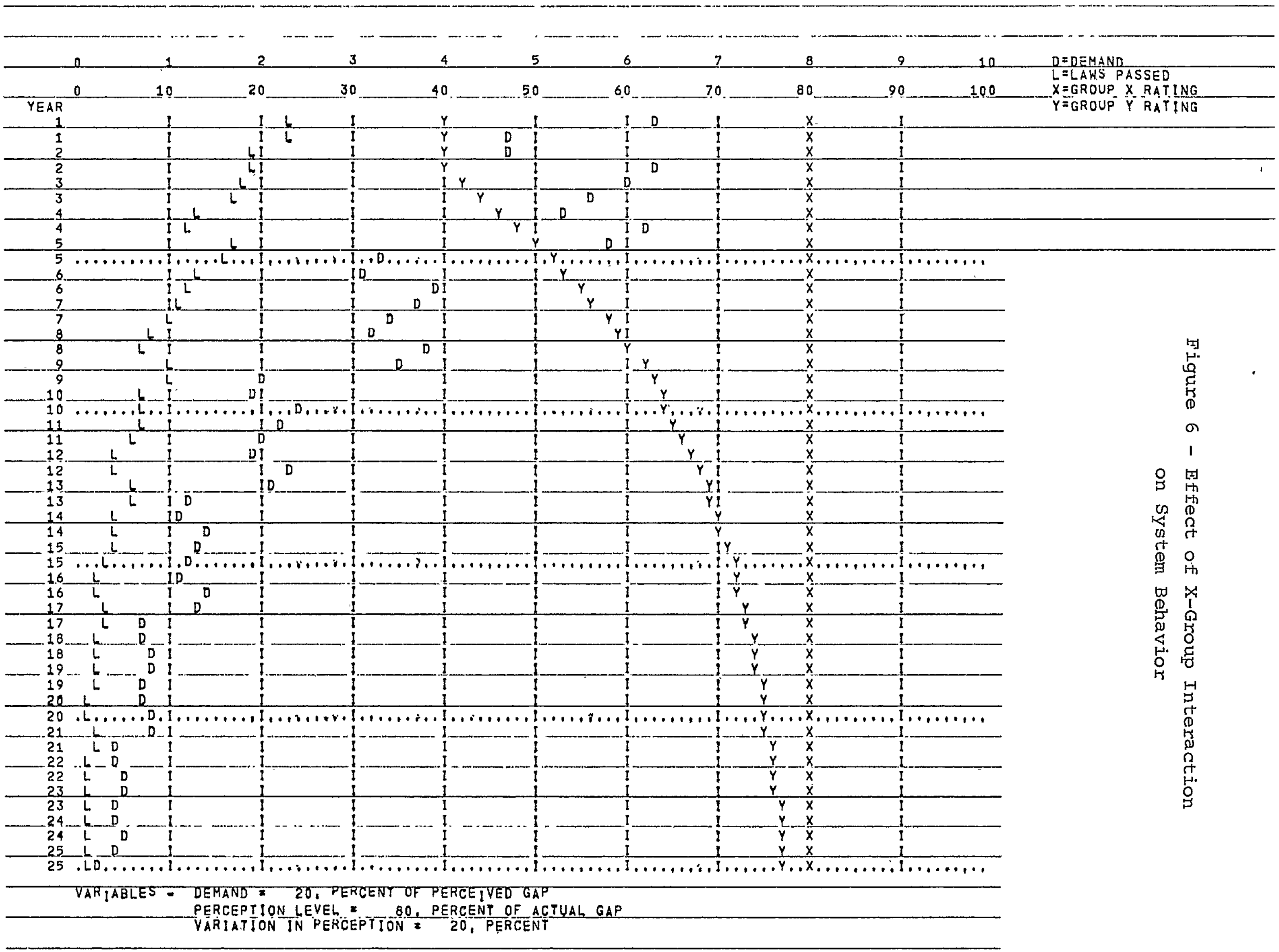


Figure 6 - Effect of X-Group Interaction
on System Behavior

Figure 7 - DYNAMO Run of Base Model - Parameters as in FORTRAN Run, Figure 3

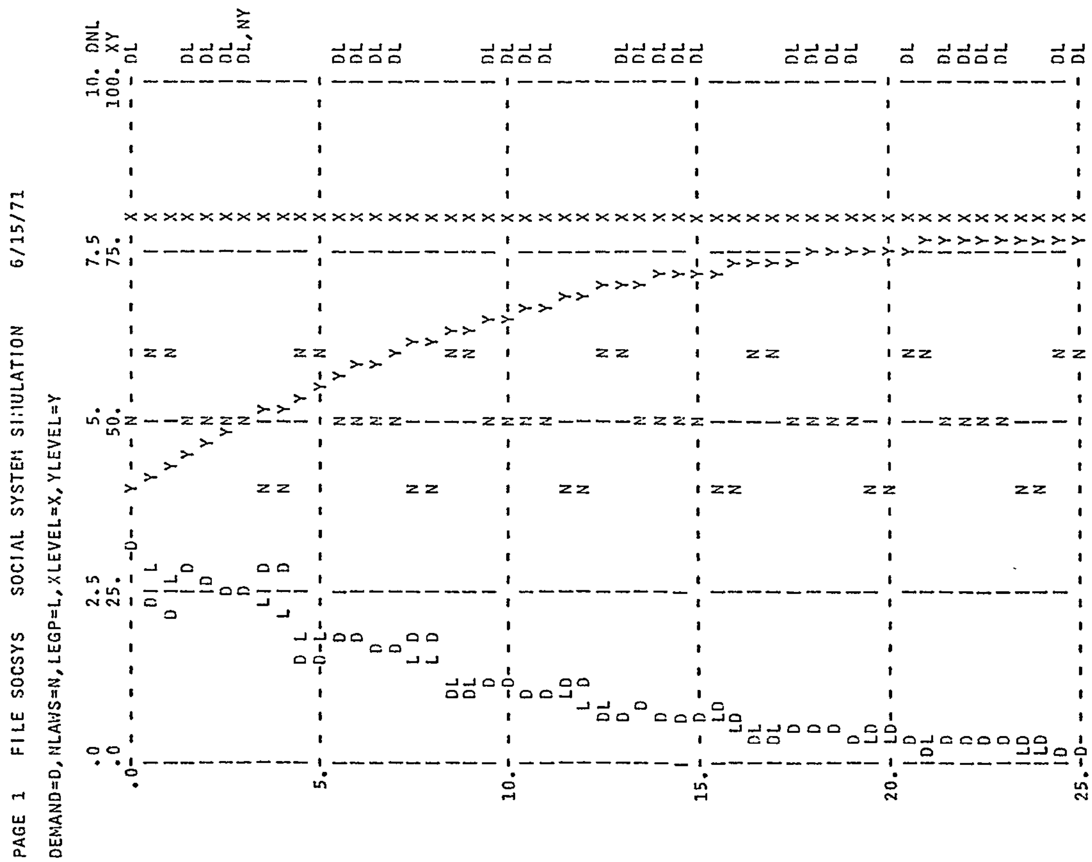
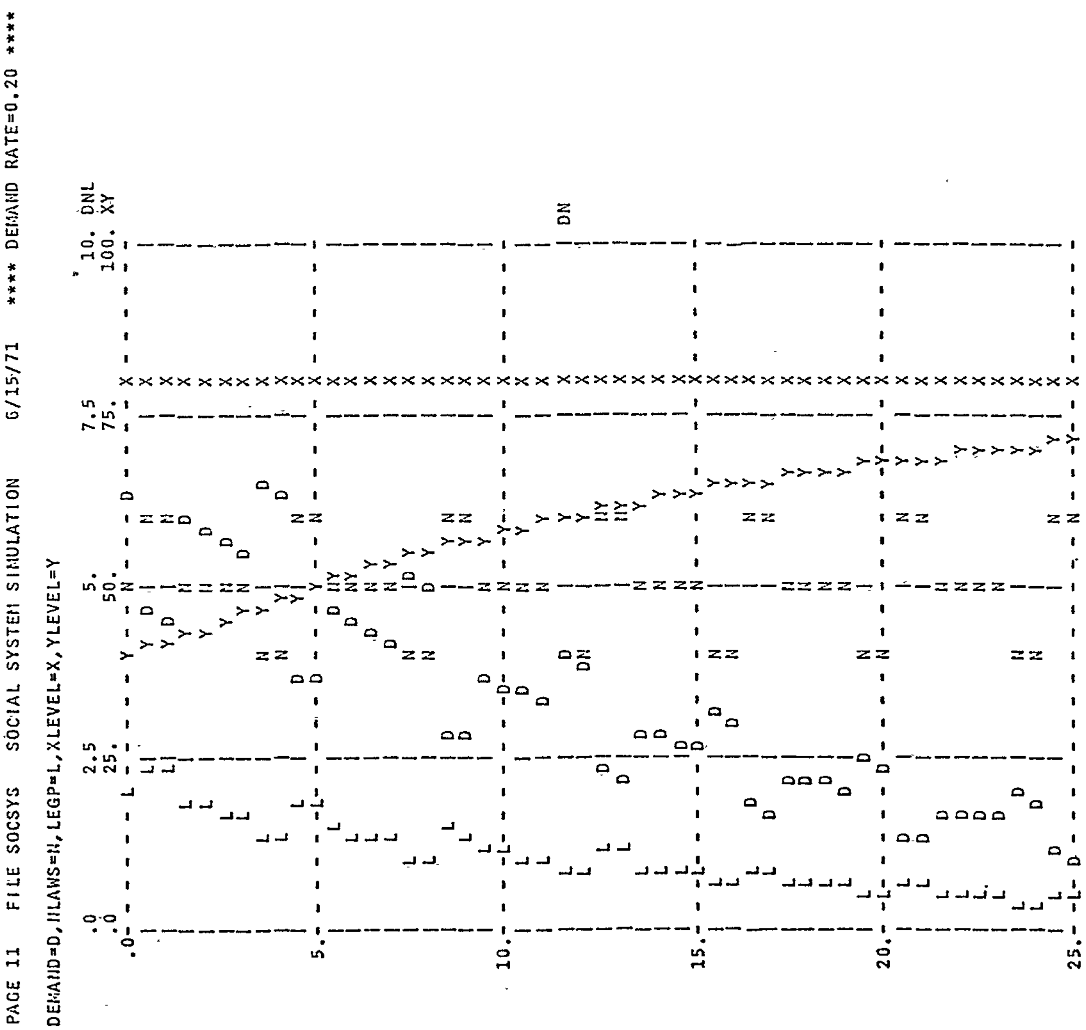


Figure 8 - DYNAMO Run of X-Group Interaction - Parameters as in FORTRAN Run, Figure 6



assumed steady-state condition. Aside from this small initial difference, the dynamic response of either simulation is exactly the same with respect to amplitudes, durations, and time sequence.

The comparison of the two languages with respect to the ease of model development and programming presents an entirely different picture. If the complete system definition, as presented in this paper, were given to two competent programmers simultaneously with their being asked to develop a FORTRAN and DYNAMO program, the difference in time and effort would be considerable. In fact, the difference could be on the order of ten or more. The reason for this differential is the amount of "overhead" programming automatically accomplished for the DYNAMO user. The DYNAMO user does not have to be concerned with initial value determination for the system RATE equations, the scaling and layout of plot routines, and the provision of functions such as TABLE, RAMP, PULSE, etc. In addition, the DYNAMO compiler checks for logic errors in model formulation (i.e., simultaneous equations) as well as language usage errors.

Those familiar with FORTRAN as a simulation language can appreciate the effort required to realize the above "overhead" necessary to support any model execution. It is also apparent that successful simulation in FORTRAN requires a relatively high degree of sophistication in the language. In the case of DYNAMO, on the other hand, a high language skill level is not required to execute simulations of a complex nature. DYNAMO's handling of the "overhead" frees the user to devote more time to analysis of the real-world system.

In summary, the experience gained by comparing DYNAMO to FORTRAN as an implementing language shows that DYNAMO greatly facilitates the realization of a running simulation model without forcing any compromises in modeling the real system. In addition, the use of DYNAMO does not require skilled programming talent and can, therefore, be immediately useful to a user without an extensive computer background.

A SOCIOLOGICAL LABORATORY

The purpose of this paper, and the development of the model discussed, has been to show that simulation methods and techniques exist to aid the social scientist in his study of dynamic social systems. The model, in its current state, is very simplified and deals with the items of concern at an extreme macro-level. However, the system behavior at this level of complexity is beginning to exceed that capable of common sense prediction and evaluation. Development of simulation models in this and other areas of concern would provide a form of "sociological laboratory" in which experimentation would be possible. The availability of social models for experimental purposes, no matter how crude initially, would be of considerable value to further social science development.

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