SIMULATION OF THE RELATIONSHIP BETWEEN CERTAIN SOCIAL FACTORS AND TRANSPORTATION IN A LOW INCOME AREA

by

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Introduction

The intent of this paper is to model a typical urban ghetto in terms of three variables -- education, health, and income -- and to simulate the aggregate and individual behavior of these variables over a ten year period. Following this, a fourth variable, transportation, will be incorporated into the simulation in an attempt to forecast the effect of improved accessibility upon overall performance in the area. Much of the format and nearly all the conceptual framework of this model is derived from J. Forrester's [1, 2, 3, 4] thinking on system structure and dynamics. Indeed, even the model design and programming techniques used here are based on concepts developed by Forrester.[5]

From this analysis it is hoped that a number of insights will emerge concerning the development of urban ghettos and the effect (or lack of effect) of transportation in helping this development. Special emphasis will be placed on discerning (1) the circular-cumulative pattern of advance among education, health, and income; (2) the dynamics of system behavior over time; and (3) the strategies for system change.

The remainder of this chapter will be used, first, to describe Lowry's[6] classification of general planning models and, second, to provide a summary of current modeling efforts. The first part attempts to relate simulation models to an accepted taxonomy while the second tries to determine the effectiveness of existing models in replicating social and economic systems.

Lowry's Classification of Models

As it is used here, a simulation model is one that duplicates the observed conditions of reality through predetermined and consistent rules for handling and manipulating data.[7] It typically treats society -- or that part of society under consideration -- as a system of interacting variables that react to data introduced into the system externally.

Defined in this way, simulation models may be said to fall into all three categories of Lowry's planning "models": descriptive, predictive, and general "planning." Each type varies in effectiveness, complexity, and purpose. According to Lowry, descriptive models replicate the essential features of an already observed process of urban change.[8] They are of value because they reveal much about the structure of the urban environment, reducing the apparent complexity of the city to the rigorous format of mathematical equations. Unfortunately, they neither satisfy the planner's demand for information about the future nor help him to choose among alternate programs. Since simulation models attempt to duplicate fully future conditions, descriptive computer models are rare and in most cases poorly developed. Their use is largely heuristic.

Predictive models are employed in forecasting the occurrence of dependent events given the occurrence of related, independent events. The most familiar of the predictive models are those based on regression analysis and simultaneous equations. Less familiar but of growing importance are those models based on canonical correlation analysis and similar multivariate techniques. Both types, though, are based on the assumption that there is a causal sequence,[9] that is, that variables are functionally related and that the direction and probably magnitude of future (dependent) events can be estimated given knowledge of their cause, which is usually assumed to lie in a select number of (independent) variables.

Although more practical and useful to planners than the simple deterministic models, most predictive models implicitly assume linearity and direct causal relationships -- a fact that violates the interrelatedness, multicollinearity, and feedback behavior of human relationships. Simulation models ordinarily attempt to integrate these structures into their format, and in this sense they may be viewed as a particular kind of predictive model.

The final class of model, the planning model, necessarily incorporates the method of conditional prediction, but it goes further in that outcomes are evaluated in terms of planning goals.[10] It is into this category that simulation models increasingly fall, possibly in an attempt to provide more effective policy guidance to planning decision makers. The essential features of these models, are to Lowry:[11] (1) the specification of alternate programs that might be chosen by the planner, (2) the prediction of the consequences of choosing each alternate, (3) the scaling of these alternatives according to a common numeric standard, and (4) the determination of an optimal solution in terms of yield on invested capital. An example of such a planning model is the EMPIRIC goal programming technique.[12] It creates and evaluates alternate policy decisions through a linear programming algorithm set to optimize a given policy objective.

Simulation models, then, differ little from the general types of planning models in terms of method and complexity. In fact, they are included in all three categories of Lowry's classification. Should a difference exist, it would seem to lie in perspective and purpose. The intent of these models is more to duplicate real world conditions in a realistic and comprehensive way than to reduce reality to a mathematically rigorous but behaviorally inaccurate format, a characteristic common to the more traditional deterministic and predictive models.

Literature Review

Since the years of the quantitative revolution in the behavioral and social sciences, which occurred in the late fifties and early sixties, the number and complexity of computer simulation programs have increased in proportion to the advances in computer design and machine language. Most of these models have originated from the economic and engineering disciplines, presumably reflecting their mathematical orientation. Sociology, geography, and city planning have contributed somewhat fewer simulation programs.

Of the social science disciplines, economics has developed the greatest number and, perhaps, diversity of simulation models. Reflecting an interest in business fluctuations and growth, economic modeling has effectively encompassed single- and multi-sector, trade cycle, and capital growth theory. The models that capture these processes range from the very sophisticated, which use linear stochastic equations as their structure, to those that rely on single or multiple estimating equations. Less varied are the geographic scales of these models. Most tend to be concentrated at the national or global scale. Very few deal with regional or local processes; moreover, the latter largely focus on the relationships of firm and market operations, and especially those relationships between the organization of land and the pattern of land rents. Not unsurprisingly, these and the other economic models stress the interconnection of economic variables. The social variables of age, health, and education are largely ignored, although this bias has partly changed in recent years. The models developed by Forrester on urban, industrial, and world dynamics have attempted to incorporate several social variables into an econometric system.

Less well developed are the simulation models emanating from sociology. Of these, the more advanced have some form of relationship with economics. In fact, the most sophisticated deal with the behavior of national socioeconomic systems such as those constructed by Martin Shubik[13] for several Latin American countries. Less advanced models emphasize the traditional thrust of sociological research, including path analysis, role playing, social stratification, peer influences, deviant group behavior, and group values. Not unsurprisingly, their intent is to discern the workings of groups and the social institutions that guide group actions. Only rarely do they examine urban conditions, and even then the analysis is oriented toward social processes, not urban processes per se.

This absence of disciplinary concern for urban conditions is attenuated only slightly by the spatial orientation of geography. As a science that measures and evaluates areal distributions, it has been forced to examine those urban processes having a spatial context. Simulation models have been constructed by geographers to capture these processes, and they have probably been most successful at replicating the diffusion pattern of information and goods, the development and use of land, and the pattern of urban-regional growth.[14] These models have, of course, a predominant spatial orientation; they therefore provide limited insight into most urban conditions.

Seemingly, only engineering and city planning have developed coherent and reasonably sophisticated models of urban conditions per se. Both are prescriptive disciplines, tending to be concerned with practical measures. Certainly the greatest contribution by engineering to the development of simulation models of urban conditions has been in transportation; the simulation routines of traffic flow and land use have nearly all originated from this field. Also important are the optimization models based on linear and dynamic programming techniques. Examples include QUADATT,[15] EMPIRIC Programming,[16] TOPAZ,[17] and the PENN-JERSEY[18] model. Each has been instrumental in assessing the impacts of policy proposals and in allocating capital facilities in an "optimal" way. City planning has made use of these models, applying each to a variety of land use and transportation problems. However, the main thrust of model research and construction in city planning has focused on the evaluation of policy impacts. These models directly correspond to the "planning models" described by Lowry. Somewhat less emphasis has been placed on the development of the more traditional gaming and predictive models. The former have been of a relatively simple nature and very largely concerned with the analysis of political processes and land use patterns, particularly those centering on the pattern of growth about capital facilities. The latter, in contrast, have dealt with a variety of urban conditions, including the processes of residential change, land development, housing deterioration, and the like. Yet none have tried to duplicate the general socioeconomic processes of the urban ghetto.

Apparently, then, the traditional academic disciplines have failed to examine the workings of the urban ghetto except in a partial and mutually exclusive way. In the main, their models have tended to be of a general nature and oriented toward both disciplinary considerations and national- and regional-level problems. The only major exception is Forrester's ground-breaking work on "urban dynamics" which deals with the interrelationship of housing, employment, and business growth and decline in American cities. Hence, the approach taken in this essay. The socioeconomic system in this study is simulated as an integrated process encompassing a small set of social and economic considerations.

The next chapter explains the conceptual framework of the model. It is hypothesized that the integrated process that is supposed to exist in the study area is based upon a kind of circular causality wherein a given cause produces a generally similar effect, that this circularity generates a cumulative advance in system performance, and that the dynamics of system behavior are very largely dependent upon the multiple feedback loops that exist among model components. These assumptions are examined at length.

Chapter II

THEORETICAL STRUCTURE OF MODEL

The model described here is based in large part on the concepts of economic growth and stagnation developed by Gunnar Myrdal in Asian Drama[1] and An American Dilemna.[2] The first book deals with the problems and preconditions to economic growth in South Asia, the second with the condition of the American Negro prior to the Second World War. Although both are of a general cast and do not precisely focus on current American economic conditions, many of the problems encountered by developing nations can be expected to be analogous to those in large urban ghettos in the United States. The conditions of underemployment, unemployment, malnutrition, poor schooling, poor health, and inadequate social capital are very much the same. Similarly the processes that create and connect their conditions are closely identical. For this reason the transfer of Myrdal's concepts of circular causation, cumulative causation, and feedback structure to this model is considered proper and valuable, and consequently, these concepts form the models's framework.

The Model

The model developed here attempts to interrelate income, health, education, and, at a later state, transportation. The general nature of the interrelationship is shown in Figure 2-1. The circuity and feedback structure of the model is evident. Not evident, but to be discussed, is the cumulative property of the interrelationship and the

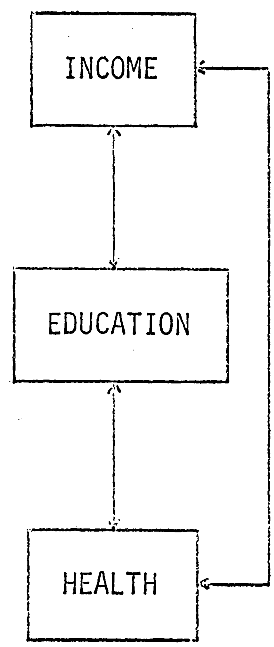

Figure 2-1. Circular-Cumulative Model

economic and social forces inhibiting circularity.

Model Circularity

Circular causation is based on a causal interdependence of factors, namely, that change in one factor produces change in the others. This is the rationale behind what is described by Nurske and Myrdal as "vicious circles" in the social processes of underdeveloped countries. Nurske writes of it thusly:

> It (the concept) implies, of course, a circular constellation of forces tending to act and react upon one another in such a way as to keep a poor country in a state of poverty. Particular instances of such circular constellations are not difficult to imagine. For example, a poor man may be weak; being physically weak, his working capacity may be low which means that he is poor, which in turn means that he will not have enough to eat; and so on. A situation of this sort, relating to a country as a whole, can be summed up in the trite proposition: "a country is poor because it is poor."[3]

Inherent to the process of circular causality is an inextricable interrelationship of cause and effect that effectively operates to imprison the social or economic system in its own shortcomings. The idea is that a given effect acts as a cause to a substantially similar effect. In short, the status quo tends to perpetuate itself through the process of circular causation.[4]

Since circularity is assumed between the education, health, and income components of the model proposed here, movement out of the low-income ghetto is difficult. "If any attempt is made to lift any part of this mesh of interlocking circles, there is usually a pull downward so that any sustained progress becomes almost impossible."[5] To illustrate, say the county board decided to use education as a lever in an attempt to break the circularity of stagnate conditions. Assume that new schools were built, new curricula introduced, and better student-teacher ratios established. At best the results of these actions would be to improve the educational level of the student only slightly. Lacking the motivation which would derive from greater chances for employment and adequate health, the ghetto student would be held back in his academic progress. Then too, there might not be any significant increase in educational skill, as measured on achievement tests, due to the predominately negative influence of the student's environment.

Circular Cumulative Causation in the Model

The theory of circular cumulative causation assumes that change in one condition causes change in one or more other conditions in the same direction. Further, it is assumed that such change is independent and additive, with the effects of one factor contributing to an improvement (or dimunition) in the other(s). Thus an initial change is viewed as supported by consequential impulses, which in turn give rise to repercussions, magnifying the initial change.[6] The process of circular cumulative causation provides, then, a theoretical alternative to the argument of stagnation proposed by the circularity concept.

It is hypothesized that health, education, and income are related to one another in this cumulative fashion. Accordingly, it is believed that additional units of income will contribute to additional increments of health and education, with the latter furthering an increase in income. It is also believed that this circular relationship can be broken at any point -- either at income, health, or education. Thus a given investment in health will produce a corresponding increase in education and income, which together generate a rise in health levels. Similarly a like investment in education will produce an increase in health and income, each of which reciprocally influence academic performance. It is not hypothesized, however, that equal units of health, education, and income generate proportional levels of cumulative advance. In fact, certain of the variables -- alone and in combination -- are more influential than others.

This last process, discussed above, is termed by Myrdal an "upward cumulative spiral" and is common to growth processes in the advanced nations of the West. But this circular cumulative process need not always exist. For example, should an initial change in one condition give rise to secondary changes going in the opposite direction, the cumulative process may be hampered, restored to an original equilibrium, or forced to move farther down an inward spiral.[7] To use a common example -- and one pertinent to the Model -- consider the effect of heightened discrimination in employment. Should such discrimination occur, it can be expected that rising unemployment will seriously hamper the attainment of improved health and education. Moreover, continued unemployment will eventually produce a cumulative downward movement of education, health, and income. It is important to understand this condition, for it emphasizes the concomitant impacts of certain actions and the importance of dealing with the interrelationships as a whole over a sustained period.

Model Feedback Loops

The dynamic behavior of systems is generated within feedback loops. To Forrester, feedback loops are the fundamental building blocks of systems and are used to control the flow of material or information at a decision point in a system. Flows are accumulated to generate "system levels," the expression of system behavior.[8]

Although there exist both positive and negative feedback loops,[9] the positive loops tend to predominate in the model structure interconnecting the level variables -- income, health, and education. These generate growth processes in which action builds a result that generates still further action.* Under their influence, the level to which the state of the system has already arisen determines the rate of still further increase. Thus the higher the system level, the faster the rate of increase in the model variables -- unless something happens to alter the parameter values in the loop equation.[10] Figure 2-2 illustrates the simplest form of loop structure.

It is this feedback structure that is so vital to the movement from a low equilibruim condition characterized by the maintenance of the status quo to the process of upward circular cumulative causation. Circular causation will give rise to a cumulative movement only when, by interaction of all conditions in the modeled system, a change in one of the conditions will ultimately be followed by a feedback

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*A negative feedback loop, on the other hand, seeks a goal and responds as a consequence of failing to achieve the goal.

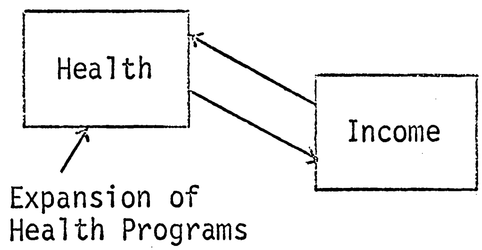

Figure 2-2. Positive Feedback

of secondary impulses to a further change of that particular condition large enough not only to sustain the primary action, but to push it further.[11] According to Myrdal:

> Mere mutal causation is not enough to create this process; otherwise the ubiquity of mutual causation would be inconsistent with the widely observed stability of social systems. . . The relationship between the size of the coefficients of response and the speed of the response (will) determine whether the mutual causation results in stable, neutral, or unstable (up and down) conditions.[12]

Factors Impeding Growth in the Model

Although positive feedback loops cause exponential growth if unimpeded, such growth normally interacts with parts of the surrounding system to modify and interrupt the growth process. Growth toward an upper limit is illustrated by Curve A in Figure 2-3. The growth process of income, education, and health approximates a somewhat flatter curve, however, reflecting a smaller coefficient and slower speed of response in the cumulative growth cycle. This relationship is depicted by Curve B in Figure 2-3. Also important in retarding growth are the linked processes of what Myrdal terms (1) independent counteracting changes, (2) counteracting changes released by development, and less ambigiously, (3) time and inertia. Each has an additive impact, and together they effectively inhibit the growth process. Each plays a role in the model, as demonstrated below.

1. Certainly the main resistance to change in a socioeconomic system stems from the behavior generated by attitudes and institutions. The latter are part of a cultural milieu and are not easily nor rapidly moved in direction or magnitude. It takes time and effort for people

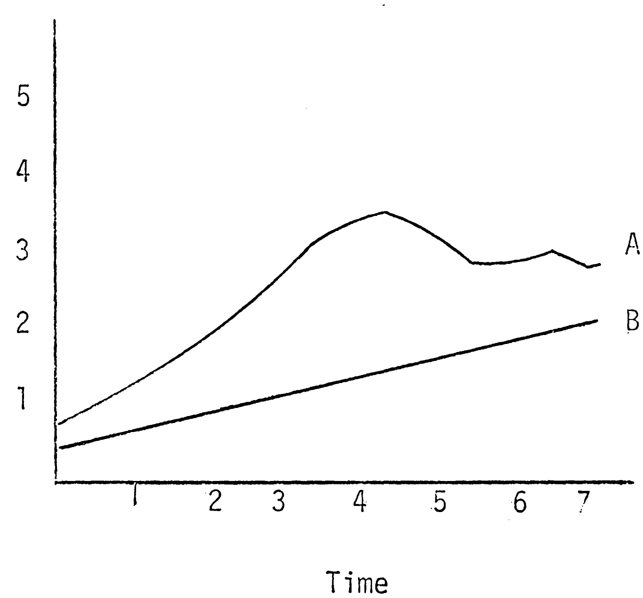

Figure 2-3 -- Dynamic Behavior of Systems to acquire discipline and habits of cooperation, to want to improve their lot, and to take risks and accept change. Similarly it takes time for the rigidities of a discriminatory social stratification that support racial attitudes to wear down in response to the improved conditions of Negroes.[13] Yet until this has occurred, it can be expected that the response to induced change -- and the speed of that response -- will be slow. The model employed here reflects these conditions through relatively large delay functions in strategic variables (see pages 54,63,65).

2. The basic assumption of uni-directional relationships within the model is on the whole realistic. Indeed, the circular cumulative process seems to provide the key to development -- or the lack of it -- in stagnant, low-equilibrium social systems. There are, nonetheless, exceptions to this rule, as when secondary changes move the system in the direction opposite to that of induced change. These are what Myrdal calls "counteracting changes."[14]

An example of a strong counteracting change is that derived from increased education. Equation 1-100 page 62, suggests that an increase in income ordinarily results with education past the twelfth grade. In the main this relationship is sound, but should the rate of growth in education be to rapid, as when -- to take a hypothetical case -- all ghetto children obtain a college education, it can be expected that the overabundance of skilled workers will cause a sharp fall in the wages of professionals. Widespread unemployment might even result. Whatever the result, it can be assumed that the economic system will return to a state of equilibrium in response to the forces of supply and demand. Ghetto residents will earn wages below those of comparably skilled white workers. Similar situations are repeated in other equations, although these tend to be more realistic of the effects produced by counteractive change.

3. The circular cumulative model is further constrained by the effects of inertia and time.

In sharp contrast to the cumulative principle of the model are not only the common experiences of low level equilibria in ghetto areas and serious obstacles to development policies, but more generally the astonishing stability of most community socioeconomic systems. "Balance, far from being the fortuitious result of an unusual and obviously unstable combination of forces, seems to be the rule, not the exception."[15] The writings of political science, sociology, and anthropology all indicate that the traditionalism of culture -- and its behavioral expressions -- work to inhibit intended change to the extent that it differs appreciably from the values of the affected group.[16]

Time is a critical element in maintaining and perpetuating such equilibrium. The reactions of other conditions to a change in one of them are seldom simultaneous but usually are delayed, often for a considerable period. An example of this is the relationship between levels of nutrition, the physiology and psychology of workers, and labor input and efficiency. A rise in nutritional levels should have some beneficial short-term effects on worker's health and willingness and ability to work, and thus on production and income. But the major effects may not be realized until a new generation of workers which has enjoyed improved nutrition from childhood enters the labor force. Indeed, sometimes there is no reaction to some of the conditions, as when the rise in nutritional levels is only temporary. As with inertia, these happenings are introduced as delay functions in certain model relationships.

Summary

The model to be described here assumes a circular interrelationship among its education, health, and income components and a cumulative advance in their system levels. The latter occurrence is believed to derive from the action of positive feedback loops. These in turn are assumed to be impeded by certain effects emanating from the environment and from certain internal growth process.

Although there is ample theoretical evidence for this form of model structure, these relationships are nonetheless assumptions and therefore are subject to verification in the later evaluation of model projections in Chapters 4 and 5. Hence the confirmation of the interrelationship -- and more importantly, the theories on which they are based -- is an important second purpose of this thesis.

Chapter III

STUDY AREA AND MODEL EQUATIONS

The model developed conceptually in the previous chapter is given discrete form here. Equations are introduced to reflect as accurately as possible the apparent workings of the education, health, and income components of the model. The transportation model is not discussed until Chapter 5.

Prefacing this discussion is a brief description of the study area for which the model equations are developed. The broad characteristics of this area should be borne in mind when the equations are explained in more detail on pages 27-65.

Study Area

The equations in this chapter are developed for a low income, predominantly black area in northwestern Miami. Occupying an area of five square miles and bounded by major expressways running east-west and north-south, it coincides with the Miami-Dade County Model City boundary. In many respects its educational, health, and income characteristics are like those of northern urban ghettos.

The Model City area, although seemingly adequate in the number of educational facilities (20), is extremely deficient in the quality of education which is provided. The educational achievement of Model City children is substantially lower than the achievement of school children in the rest of Dade County, a predominantly white, middle class section of the Miami region. For example, Model City senior high school students (12th grade) at Miami Northwestern scored 5.3 years behind seniors at Miami Coral Park in reading and 9.0 years years behind the Coral Park seniors in mathematics. Similarly the percentage of ghetto children dropping out before high school graduation is significantly higher than the percentage of other Dade County school children. In the Model City area, the dropout rate is 28.6 percent, nearly eleven percent above the rest of Dade County. There deficiencies are translated into an adult population lacking suitable education for employment. Forty-one percent of Model City residents between eighteen and twenty-one years of age have not completed high school; similarly, thirty-eight percent between the ages of twenty-two and thirty have not graduated from high school.[1]

Although some progress has been made in the last twelve years toward increasing the number of available clinics and physicians and decreasing the number of deteriorated housing units, morbidity rates in the Model City's area are still markedly higher than those in the remainder of Dade County. These levels are reflected in statistics from the health section of the "Dade County Model City Program." Specifically, twenty-five percent of the clinic services provided by Jackson Memorial Hospital, used by the County's indigent, are to Model City residents although ghetto residents make up only six percent of the total county population. Similarly the death rate 0-64 years in the nonwhite population in Dade County is twice that for whites; the study area is ninety-five percent nonwhite. Finally, the death rate for infants, perhaps the best measure of health levels, is sixty-one deaths per 1,000 in the Model City area as compared to twenty-two per 1,000 in the remainder of Dade County.[2]

Income levels and their principal determinant, employment, are both extremely low in the study area. Each is strongly suggestive of the differential impact of discrimination in the Miami labor market. To illustrate, the mean imcome (1970) of Model City residents was only \$4,246 as compared to the \$8,827 for the Miami area as a whole. Employment statistics are similarly skewed. Approximately thirty-six percent of ghetto heads-of-household are unemployed, whereas the unemployment rate for the Miami area is only four percent. More important, of those Model City residents employed, most have jobs in the relatively low paying blue collar (forty-four percent) and service (thirty-six percent) trades. Only nineteen percent are employed in the white collar work force.[3]

Residents of the Model City area are moderately dependent upon transit for transportation, there being an average of 0.80 automobiles per household in the ghetto area as compared with 1.12 per household for the rest of Dade County. Transit service in terms of area coverage and frequency has been described officially as "adequate."

> The service is downtown-oriented and therefore somewhat deficient in serving other destinations of Model City's residents. In comparison with the automobile, one-bus rides take as much as three-times the time required to reach the same place by auto. If an additional bus ride involving a transfer is included, the ratio of bus to auto travel time increases four-to-one. Two major travel attractions for Model City residents -- downtown and Miami Beach -- require 45-minute bus rides from the community. Other areas accessible only by a two-vehicle ride frequently require travel times in excess of an hour. In terms of employment accessibility, a 20-minute auto trip brings Model City's residents within reach of eighty percent of the jobs in Dade County; the same travel time by bus permits access to five percent of the county's employment opportunities.[4]

In short, the study area may be described as a low income black ghetto. Its education, health, and income levels are typical of comparable areas in the North and West. Only transportation seems to be marginally adequate in terms of serving the basic social and economic needs of the area. Although not mentioned, it must be noted that the other social and demographic conditions in the study area are similarly deficient. There is an exceptionally high population density in certain sections of the Model City area, a high number of female heads-of-household, a large number of families with more than three children, a conspicuously expanding population pyramid, a high crime and delinquency rate, and an excessive number of divorces and unwed mothers. These only serve to exacerbate the low education, health, and income levels of the ghetto. Their effect is to neatly entrap the study area in a kind of circular, downward-or stagnate cumulative spiral of the type described on pages 11-13.

Model Equations

The equations described in this chapter are taken from the printout contained in Appendix I. An examination of this printout will reveal that the model is divided into three sections: education, health, and income. Although each part is relatively self-contained, the organization of each is generally similar. A series of linked equations, which are allowed to vary, estimate the behavior of a model component (as, for example, education). Since these equations are expressed as mathematical functions, component behavior is arrived at by simply adding the various equations together. This behavior is expressed in terms of a "level" variable. A level variable provides, then, according to Forrester, an index of system performance. In this model, level variables are used to transfer information from one model component to another (health or income, or both). As a result, the circularity of factors needed for cumulative growth (pages 14-16) is satisfied.

The format of each of the major, or linked, equations in the three submodels is identical. A coefficient is used to show the contribution of a particular variable to an index of the system, discussed above. An example of such an index is the dropout rate in the educational component. This coefficient is presented in terms of a function which expresses the exact nature of the contribution to the index variable under conditions that are known to exist in the study area. (The value of the coefficient is determined through multiple regression analysis.) Typically these functions are portrayed as programming statements that duplicate the relationship between two variables. Accordingly, as the function changes in value, so will the contribution of the equation to the index variable. The index variable changes correspondingly. An example will explain this process more clearly. Equation 1-7, page 35, expresses the relationship between the student-teacher ratio and the dropout rate in the study area. The coefficient assigned to Equation 1-7 is 0.01. The magnitude of the dropout rate is expressed through the expression DROPTS. As DROPTS varies from 28.98 to 28.70, the contribution of the function to DROPTS changes from .28899 to 28871. The term DROPTS expresses the overall contribution of Equation 1-7 to the education component. Adding the several (seven in the education submodel) linked equations together results in an estimate of the performance of the educational component.

The value of the function in these equations is introduced by one of two means. It can be introduced through hierarchically linked equations that approximate the condition of the function over time or through feedback loops from related equations in different submodels. The function tends to increase in an arithmetic fashion in the former; in contrast, a geometric change in the interrelationship between the variables described by the function may result from the close to exponential growth generated by the latter. The equations in Equation 1-7 are illustrative of the equations of the hierarchial type. The equations in 1-36 are typical of the feedback kind. When combined, these processes generate the dynamics of system behavior.

It is important to emphasize at this time the importance of the three index variables. They are meant to express the general condition of the study area over the period 1960-1970. Besides the dropout rate in the educational component, morbidity rates and income levels are used as index variables in the health and income submodels, respectively. It will be recalled that changes in these variables are produced by change in the equations that estimate system behavior. The general condition of the model, and the conclusions of this analysis, are therefore predicated on the accuracy of each index in representing the actual behavior the system over time.

A. Education

The assumed interaction in the educational component is shown in Figure 3-1. Of the many factors that affect academic achievement, eight were identified through regression analysis as significant. Nominally important were the teacher-student ratio, teacher quality, school facilities, and health. Of greater importance were student body quality, student economic background, and student family background. Each contributed a significant amount to the total variance of academic performance, as measured by performance scores[5] and, less directly, by dropout rates and attendance statistics. A constant is included in the model to accumulate the unexplained variance.

1. Student-Teacher Ratio

A small but positive contribution to academic performance is believed to derive from a low student-teacher ratio. Although at variance with the findings of the Coleman Report, which determined "a consistent lack of relationship to achievement among all groups under all conditions to adjustments in the ratio,"[6] and the writings of Kohl, Clark, Kozol, and Herdon which suggest "that smaller classes and better counseling (do) not constitute sufficient solutions to the failure of schools,"[7] this relationship does find support in the writings of educational theorists. Articles by Edward[8] and Keliher[9] report a significant contribution by the teacher to student achievement. They also report evidence of a strong relationship between the child's emotional development and frequent communication with the instructor. Edward maintains that "inharmonious classroom relationships

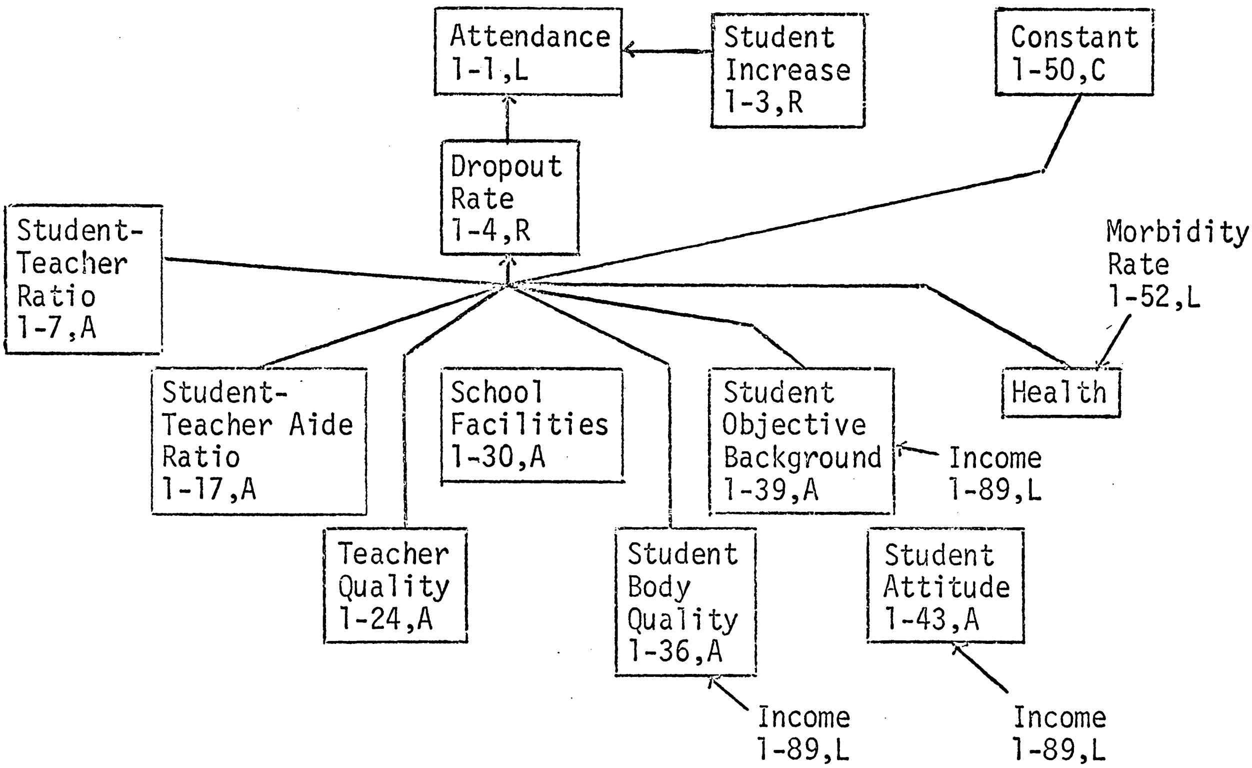

Figure 3-1 -- The Educational Component of the System Model

NOTE: An incoming arrow to a variable indicates an input of data from another model. Those without an arrow imply that data is supplied internally through the interaction of positive and negative feedback loops.

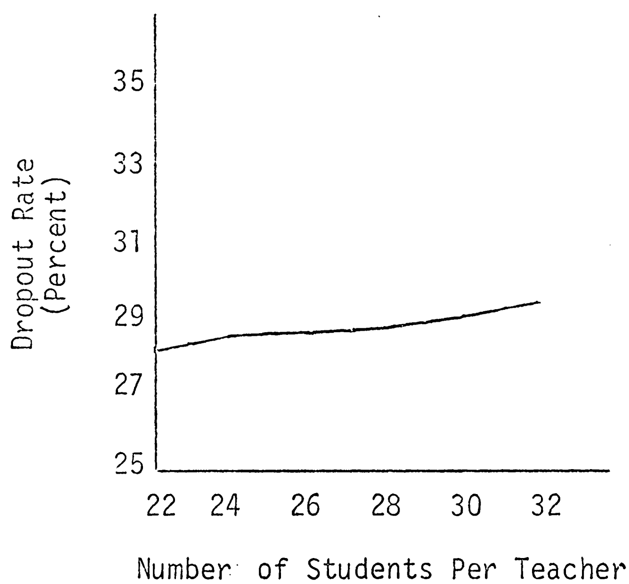

Figure 3-2 -- The Dropout Rate as a Function of the Student-Teacher Ratio

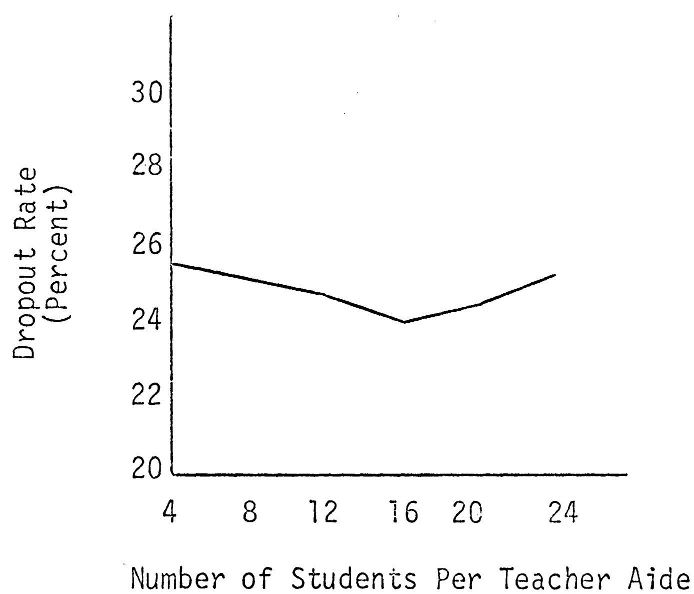

Figure 3-3 -- The Dropout Rate as a Function of the Student-Teacher Aide Ratio

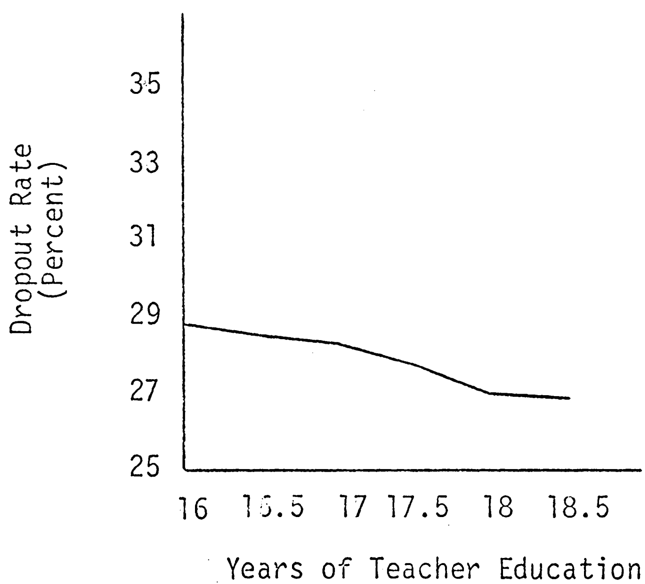

Figure 3-4 -- The Dropout Rate as a Function of Teacher Quality

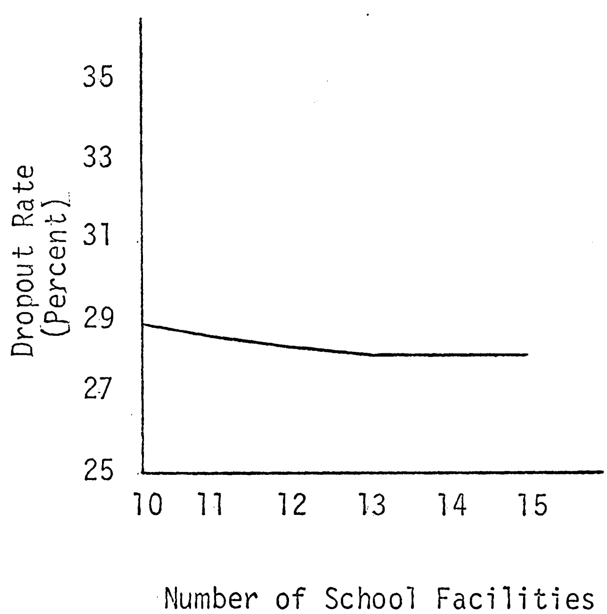

Figure 3-5 -- The Dropout Rate as a Function of the Number of School Facilities

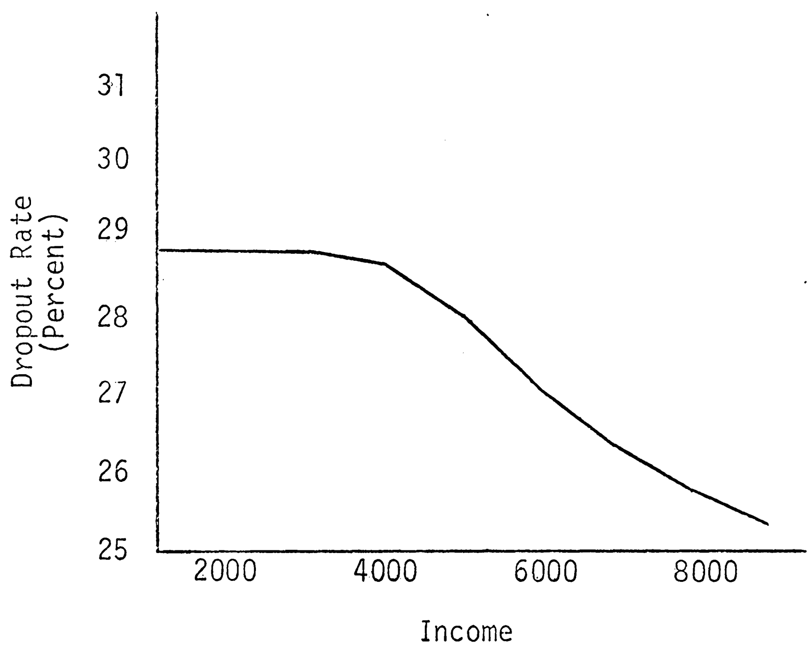

Figure 3-6 -- The Dropout Rate as a Function of Student Body Quality

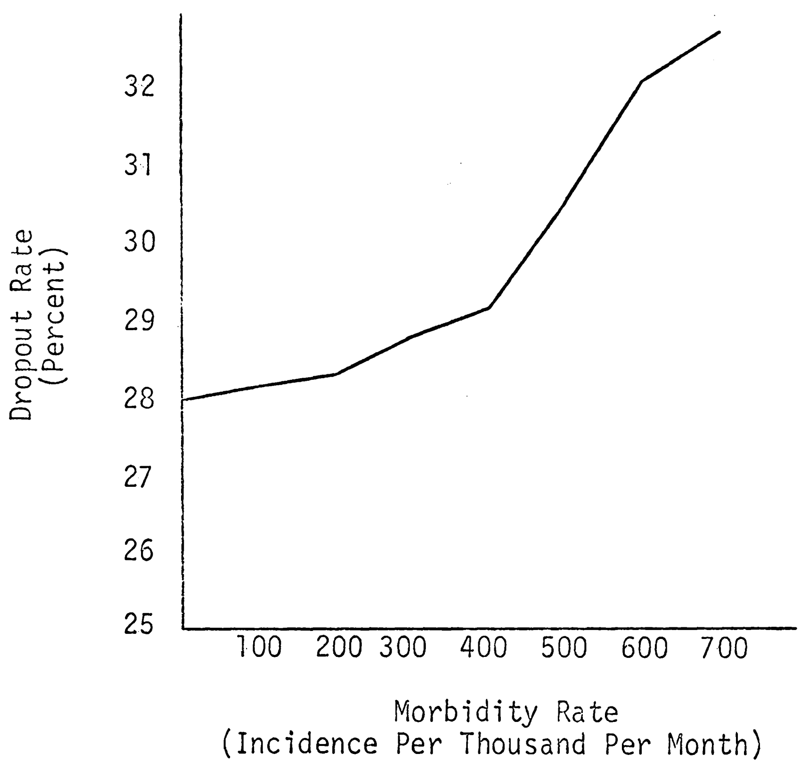

Figure 3-7 -- The Dropout Rate as a Function of the Morbidity Rate (resulting from overcrowding) mitigate against the development of social skills necessary to good personal and social adjustment."[10] Keliher and Cannon[11] in their study relate the effectiveness of such skills to academic performance. Hence the seeming validity of a low teacher-student ratio to academic achievement as expressed in Equation 1-7.*

DROPTS.K = DRPTS.K * (.01) 1-7,A

The exact nature of the relationship between the student-teacher ratio and the dropout rate is given in Figure 3-2. The relationship is only slightly positive. Change in the ratio will affect only slight modifications in the dropout rate. This conforms to the logic advanced by several prominent educators, notably Kohl and Clark,[12] and suggests the futility of making adjustments in this ratio to improve academic achievement. Change in the ratio itself is introduced in the model through a series of equations relating increases in the student population to like increases in the number of teachers.

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*The figures to the right of the equation (as, for example, 1-7) identify the location of the equation in the model, contained in Appendix I. The letters "L," "R," and "A" refer to the type of equation; there are three kinds of equations used in the DYNAMO programming language. "L" refers to a level equation; this equation expresses the behavior of some component in the model over time. "R" identifies a rate equation; these are used to regulate the flow of material or information to and from a level equation. According to Forrester, "rate equations are the statements of system policy. They determine how the available information is converted into an action stream."[13] They are, in short, the strategic variables or "decision points" of a system. "A" denotes an auxilliary equation. Auxilliary equations are the building blocks of a dynamic system model; they are used to estimate and project the essential characteristics of model behavior to a horizon year. They are always related to rate equations, and in the model developed here, are linked to the rate equations in a hierarchial manner. Appendix II provides a definition of terms used in the model.

2. Teacher Aide -- Student Ratio

Associated with the teacher-pupil ratio is the effectiveness of nonteaching paraprofessionals -- teacher aides, VISTA volunteers, and Teacher Corps members -- to academic achievement. Several descriptive studies report an improvement in school grades using these personnel. Richardson (1969),[14] Bahr (1969),[15] and Weed (1969),[16] all suggest that "projects of this type tend to improve the communication process between student and teachers with respect to subject matter context through the use of highly trained professionals."[17] Statistical studies report mixed results. Freund (1965)[18] showed that children "improved significantly in attitudes and other skills, while there was no significant academic growth as measured by achievement test scores."[19] A study by Taylor (1970)[20] using chi-square tests as criteria revealed "a significant impact upon student performance in the positive direction,"[21] Thus there is evidence to suggest a measurable impact by teacher aides upon the student's academic work, and particularly upon his emotional health.

DROPTA.K = DRPTA.K * (.015)   1-17,A

The model suggests a positive (.015) relationship between the use of teacher aides and academic performance. The relationship is curvilinear, of the type described in Figure 3-3. Their effectiveness tends to first increase with class size and then decrease, being greatest with groups of 15-20; Edward[22] maintains that groups of 15-18 are the optimal size for work with disadvantaged children. Needless to say, this relationship only exists if the aides are well prepared and are understanding of the needs of children.

Change in this ratio is introduced in the same fashion as the student-teacher ratio, that is, through a series of rate and level equations that change the value of DRPTA in Equation 1-17. Change is expected to be .05 percent per year. A base of two (teacher aides) is given. Hence the value of the ratio changes fairly rapidly, affecting the contribution of Equation 1-17 to the dropout rate in like fashion.

3. Quality of Teaching Staff

According to the Coleman report, the characteristics (education, salary, verbal ability) of teachers are second only to the characteristics of the student in their impact upon academic achievement. Perhaps more important, the quality of teaching seems to have a greater impact upon Negro children than upon any other group. Using this factor alone in a regression analysis, Coleman's analysis found that it explained some 9.53 percent of the total variance in academic achievement by Negro children but only 1.82 percent for white children. This relationship corresponds roughly to the generally greater sensitivity of the minority student to his school environment.[23]

The implication is that the effect of good teachers is greatest upon minority children, and that a given investment in upgrading teacher quality will have the most effect on achievement in underprivileged areas.[24] Equation 1-24 expresses this relationship. Quarter-years of education past the college degree are used

DROPTQ.K = DRPTQ.K * (.019)	1-24,A

to reflect the quality of teaching personnel, and is expressed by the varying magnitude of DRPTQ. Use of this index is supported by Coleman who found a strong (positive) correlation between student academic achievement and the academic preparation of teachers.[25].

The exact relationship between teacher quality (DRPTQ) and academic performance is given in Figure 3-4. A curvilinear association exists, with the effects of teacher quality increasing with years of advanced education. The model postulates a base of sixteen years education with annual increases of .05 in schooling. As change in the ratio proceeds, this value is entered into DRPTQ, causing the degree of contribution to academic achievement to rise.

4. School Facilities.

A general relationship exists between educational achievement and the resources available to the student. Nonetheless, this relationship is slight; at the national level school facilities account for only 4.24 percent of the variance explained on achievement tests, and only 5.66 percent in the South.[26] Equation 1-30 reflects this generally small relationship. The rate of building construction (DRSF) is used as the measure of contribution by school facilities to academic performance.[27]

DROPSF.K = DRSF.K * (.017) 1-30,A

Figure 3-5 depicts this relationship as curvilinear, with initial increases in the number of school facilities generating the greatest advances in academic performance. The model assumes a base of ten facilities for the study area and an annual increase of .05 in school facilities. Advances in this relationship are entered through DRSF in Equation 1-30, altering the contribution of Equation 1-30 to the dropout rate.

5. Student Body Characteristics

One of the main conclusions of Equality of Educational Opportunity concerns the effect of other children upon a student's academic achievement. Coleman found that the "attributes of other students accounts for far more variation in the achievement of minority group children than do any attributes of school facilities and slightly more than do attributes of staff."[28] Apparently, as the "educational aspirations and background of fellow students increase, the achievement of minority group children increase."[29]

The higher achievement of minority group children in schools with a greater proportion of white students is largely, perhaps wholly, related to the effects associated with the student body's educational background and aspirations. This comes not from racial composition per se, but from the better educational background and higher educational aspirations that are, on the average, found among white students.

The effects of the student body environment upon academic student achievement appears to lie in the educational proficiency possessed by that student body, whatever its ethnic or racial composition.[30]

DROPSQ.K = DRSQ.K * (.080) 1-36,A

Equation 1-36 relates these findings to the income levels of the study area. Income is used here as a rough surrogate for the educational aspirations and backgrounds of the student body, since both mirror the occupations and education of parents. The exact form of the relationship is given in Figure 3-6. The effect of income is basically linear, educational performance increasing with rising income. A deviation from this relationship occurs at the $4,000 level. At that level and below, income has absolutely no impact upon academic performance. Harrison attributes this to the sense of frustration and bitterness associated with low income jobs. Apparently the parents translate this frustration into a feeling of futility with the educational process that is assimilated by their children.[31]

Change in their relationship is introduced in a different manner than in Equations 1-7, 1-17, 1-24, and 1-30. Instead of being entered indirectly through a series of hierarchially related rate and level equations, it is induced directly from the level variable, Equation 1-89, of the income submodel. This is an example of a positive feedback loop, the first introduced so far. Its effect is to increase exponentially the value of DRSQ in Equation 1-36.

6. Background of Students

DROPSB.K = DRSB.K * (.157) 1-39,A

Equation 1-39 relates academic performance to the economic and emotional background of the student. It is hypothesized that this relationship is vitally important, accounting for nearly sixteen percent of the total variance in academic performance - and that it is second only to student attitude in the contribution to this performance. As with the previous equation, income is used as a surrogate for the economic and subjective background of the student. The value of DRSB is entered directly from the income submodel. The character of this relationship is assumed to be identical to that depicted in Figure 3-6.

The subjective component of the equation is especially important during the high school years. Almost without exception, Negro parents have an exceedingly high interest in their children's education, and nearly all believe that their children should have a better occupation than they. This interest, however, is not translated into practices that support the child's achievement. As a result, the child does not develop behavioral patterns to succeed academically, and a kind of emotional reaction sets in that negatively affects the child's attitudes toward himself and his social environment.[32] The high coefficient in Equation 1-39 underscores the surprisingly high interest by ghetto parents in their child's development and, correspondingly, the parent's inability to translate this interest into effective learning patterns.

7. Attitudes of Students

Recent research has indicated a high self-concept as well as a high interest in school and learning by Negroes. Blacks, however, seem to have a much lower sense of control over the environment than do whites.[33]

It is this lack of control that seems to undercut the academic advancement of the ghetto youth. Lacking such control, the children interpret the environment as capricious and hostile.[34] Responses to survey questions like "good luck is more important than hard work for success" or "people like me don't have much of a chance to be successful in life" are consistently affirmative. As a result of this orientation, "the virtues of hard work, of diligence and effort toward achievement appear to a child. . . .as unrewarding. . . . the child is more likely to adjust to his environment, finding satisfaction in passive pursuits."[35]

Since testing research has established that a sense of control over the environment has the strongest relation to achievement, and that minority children who do exhibit a sense of environmental control receive considerably higher achievement scores than those who do not,[36] Equation 1-43 is formulated as having a vital influence. Of the nine

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DROPSA.K = DRSA.K * (.171)   1-43,A

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equations in the education submodel, it has the greatest single impact. It also has important feedback ties to income, as expressed by the availability of good jobs. The possibility of future employment provides the impetus to hard work and learning discipline during the high school years, report Zito and Bardon[37] in their analysis of student motivation.

The value of income is introduced directly from the income submodel through DRSA.K, in the manner described for Equations 1-36 and 1-37. Figure 3-6 approximates the effect of income upon student attitudes.

8. Health

Equation 1-46 relates the effect of morbidity upon education. Research by Albert[38] (1967) suggests that there is little impact by improved health on academic performance. In a study of illness and

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DROPH.K - DRHP.K * (.05)   1-46,A

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health care among low-income children, he found that very few symptoms of illness actually result in a physician being called or the individual being taken to a clinic. Nor are children kept home from school. As a result, poor health may not be reflected in diminished school attendance, which is often equated to academic performance in ghetto schools.[39] Accordingly, an increase in the quality and quantity of health care programs may have a negligible impact upon the dropout rate. This relationship is suggestive of Myrdal's contention that health plays a minimal role in economic and education growth in industrial countries, since their levels of health are already quite high.[40]

The precise form of the relationship is shown in Figure 3-7. A curvilinear function is thought to exist, with significant advances in health needed to measurably decrease the dropout rate. The value of health is entered from the health submodel through DRHP in Equation 1-46.

B. Health

A review of the literature, complemented by correlation and stepwise regression analysis, seems to indicate a fairly direct and significant relationship between the health levels of a ghetto area and five factors. The latter include the physician ratio, the availability of health facilities, the amount of deteriorated housing, and, to complete the circular relationship among the submodels, the level of education and income. The interrelationship of these variables is depicted in Figure 3-8. The contribution of each to morbidity rates, a surrogate for health levels, is given by a coefficient identified through multiple regression analysis. Variance not explained by the five factors is accumulated by a constant, in the manner of the constant used in the education submodel.

1. Physician Ratio

According to Robinson (1965)[41], Salisbury[42] (1969), and Lashoff[43] (1971), the level of ghetto health is measurably affected by the number and availability of physicians. Significantly, this supply is inordinantly low. Physicians have moved from their former central city locations to the more affluent suburbs, in response to the migration of the white middle class. Lashof (1965) found that in Chicago there

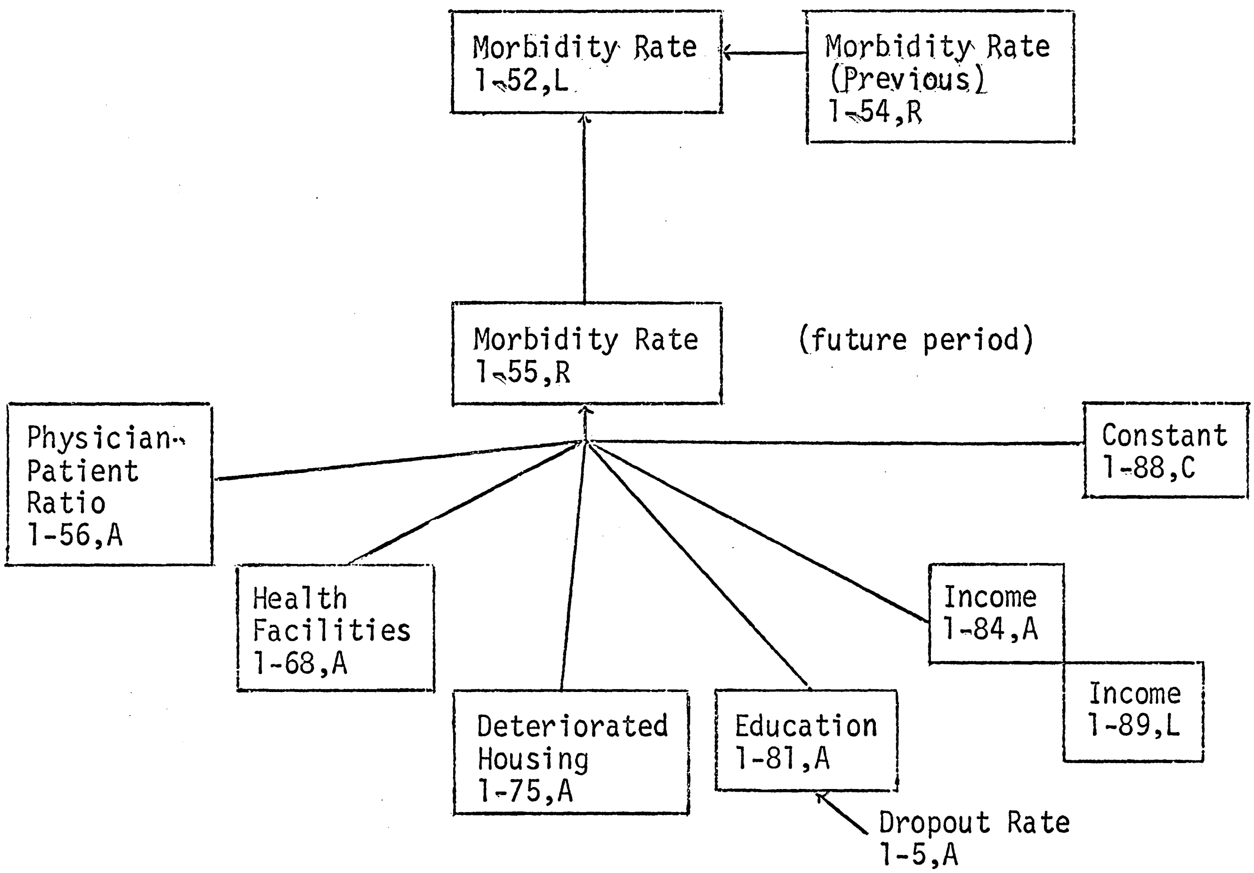

Figure 3-8 -- The Health Component of the System Model

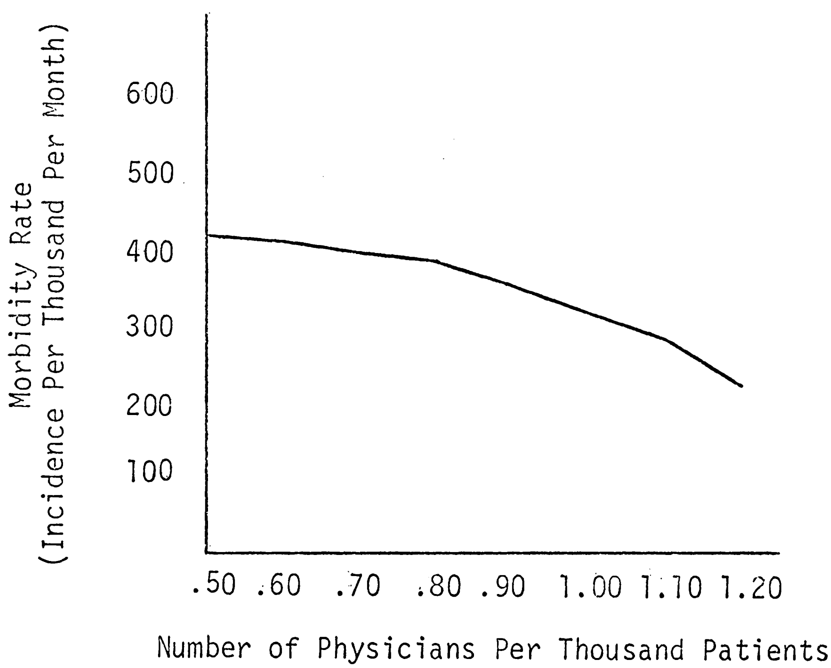

Figure 3-9 -- The Morbidity Rate as a Function of the Physician-Patient Ratio

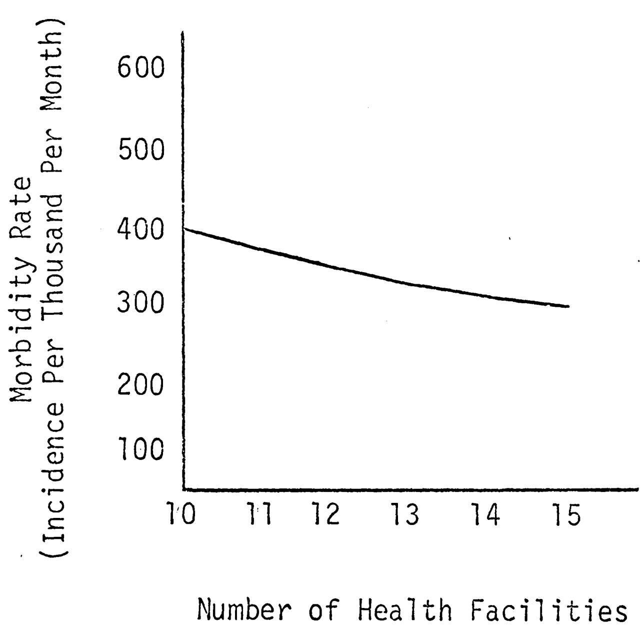

Figure 3-10 -- The Morbidity Rate as a Function of the Number of Health Facilities

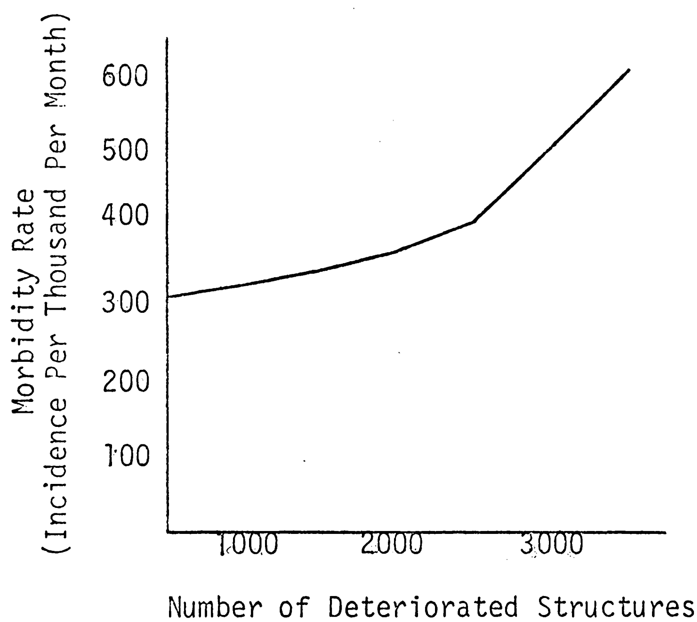

Figure 3-11 -- The Morbidity Rate As a Function of the Number of Deteriorated Structures

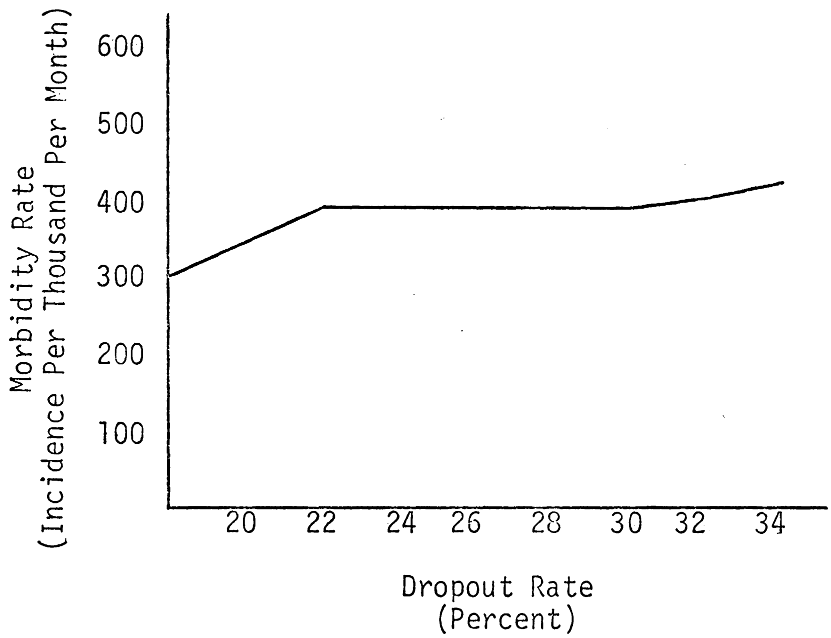

Figure 3-12 -- The Morbidity Rate as a Function of the Dropout Rate

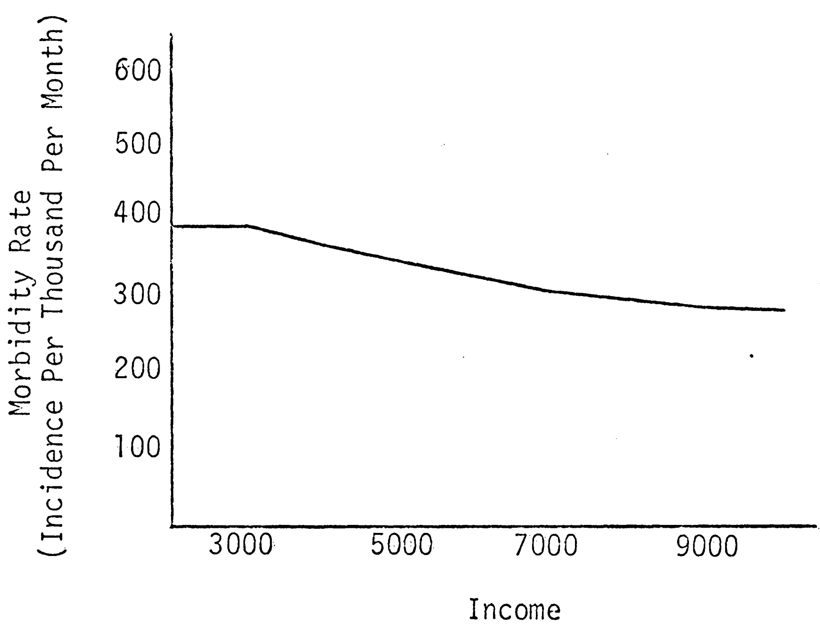

Figure 3-13 -- The Morbidity Rate as a Function of Income were 1.26 physicians per thousand people in nonpoverty areas but only 0.62 per thousand in poverty areas.[44] Similar ratios were believed to exist for the study in Miami. The effect of this migration has been to reduce the quality of health care in the ghetto and to throw additional burdens upon already strained urban facilities. Equation 1-56 relates these findings to the morbidity rate.

HPHYRT.K = HPHRTP.K * (.10) 1-56,A

The exact character of this relationship is presented in Figure 3-4. A declining curvilinear relationship is postulated, with the greatest effect coming at the .80 ratio level. Below this level there seems to be little impact of physician availability on health levels. The physician ratio in the study area is about .76.

Change in this ratio is derived from rate and level equations which relate population growth to the physician growth rate. This value is entered through HPHRTP, causing the contribution of the physician ratio to the morbidity rate to vary.

2. Health Facilities

The level of ghetto health is, of course, very much dependent upon the number and availability of health facilities. This relationship is particularly critical in ghetto areas because of (1) the tendency by ghetto residents to prefer public clinics over private physicians; (2) the relatively high proportion (thirty percent) of ghetto residents on welfare, most of whom are required to use municipal facilities; and (3) the dependence of ghetto residents on transit. The last is cited by Salisburg[45] and Robinson[46] as especially critical to the reduction of ghetto morbidity rates. Such research suggests the necessity to either improve the accessibility of ghetto health facilities or to locate these facilities throughout the community in the manner of neighborhood health centers.

The coefficient in Equation 1-68 suggests the importance of this proximity factor to morbidity rates. The effect of transportation is introduced through a constant that subtracts a given quantity,

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HFACS.K = HFACSP.K * (.30)   1-68,A

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equivalent to the inaccessibility of ghetto residents to suburban health facilities, from the total urban accessibility to these facilities. Change in the number of facilities is introduced through HFACSP, and is given in the model as a .01 percent increase per year. Figure 3-10 indicates the general nature of the relationship between health facilities and the morbidity rate. The slight (inverse) curvilinear relationship suggests that the effects of change will be minimal.

3. Housing

Recent statistical and psychological research has indicated an inverse correlation between poor, overcrowded housing and the quality of mental health.[47] Other research, largely of a statistical nature, has suggested a comparable association with physical health. Among the latter are the correlation studies of Libowitz[48] on Alameda County, California, and Bedger[49] on Cook County, Illinois. A descriptive study by Wilner[50] presents convincing evidence of the same relationship. Equation 1-75 reflects the importance of deteriorated housing,

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HH.K = HOUSIN.K * (.07)   1-75,A

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suggesting that the slum environment has a generally deleterious effect upon health and that the incidence of certain specific diseases may be related to certain specific components of housing quality.

An inverse curvilinear relationship is thought to exist between health and poor housing (Figure 3-11). Change in the relationship is introduced through HOUSIN from equations that determine the number of deteriorated structures in the study area. The rate of change is given as -0.031; a value of 2210 is used as a base.

4. Education

In contrast to Equation 1-46, which described the effect of health upon academic performance, improved education (Equation 1-81) seems to produce nearly proportional advances in health knowledge past a given level (it is assumed, but not proved, that increased health knowledge results in improved levels of health.) Wade's [51] study of public attitudes about illness in a national survey suggests the following relationship, where percentage indicates the knowledge by an individual concerning some significant health condition:

Less than High School Education	28%
High School Education	51%
Some College	56%
College Graduates	81%

The effect of education on health knowledge is, apparently, especially marked at the high school level and at the college graduate level. According to Wade, the high school level of education "encourages one to seek further information and enables one to comprehend that information." Previous to that level, education seems to have a negligible effect, probably for exactly the opposite reasons.[52] Figure 3-12 depicts this relationship. Note that a substantial decrease in the dropout rate is required to affect health levels inside the study area. The dropout rate in the Model City area, you will recall, is 28.6 percent.

Change in this relationship is introduced through a positive feedback loop from the education submodel through HEDUCP.K in Equation 1-81. Ghetto cultures are, however, reluctant to accept the

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HEDUC.K = HEDUCP.K * (.123)   1-81,A

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different ideas and patterns of behavior that formal schooling suggests. Persistent and forceful leverage must be applied if the effects of health programs are to be fully realized. And even then, ghetto values and attitudes are not rapidly altered.[53] As a result, a sizable delay normally exists between the start-up of programs and their impact upon cultural values. This condition, for obvious reasons, exists between education and health practices; accordingly, a first-order delay function (SMOOTH) is included in Equation 1-81.

5. Income

The impact of increased income follows a curvilinear path, of the type shown in Figure 3-13. A study by Bedger[54] (1966) of socioeconomic characteristics and their relationship to maternal and child health reports that infant mortality rates steadily decrease as incomes increase. Yet he also found that after a certain minimum of income, additional income has little effect on health factors. The most significant change in morbidity rates apparently occurs below the $6,000 income level, and particularly when the income level is $4,249 and less. Accordingly, increases in income can be expected to noticeably effect health levels to the $6,000 income level, but not beyond that. Significantly, the median income in the study area in 1960 was $3,030.

Income is introduced from the income submodel through HINCP.K in Equation 1-84, completing a positive feedback loop between health and income. Because this forms an exponential increase in health levels,

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HINC.K = HINCP.K * (.20)   1-84,A

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rising income plays a vital role in reducing morbidity rates. The high coefficient of contribution (.20) accentuates this impact.

C. Income

Five variables were identified as critical to income levels in ghetto areas. These included age, education, health -- all forms of social capital -- plus the more obvious economic factors of discrimination and employment. The assumed interrelationship of these variables

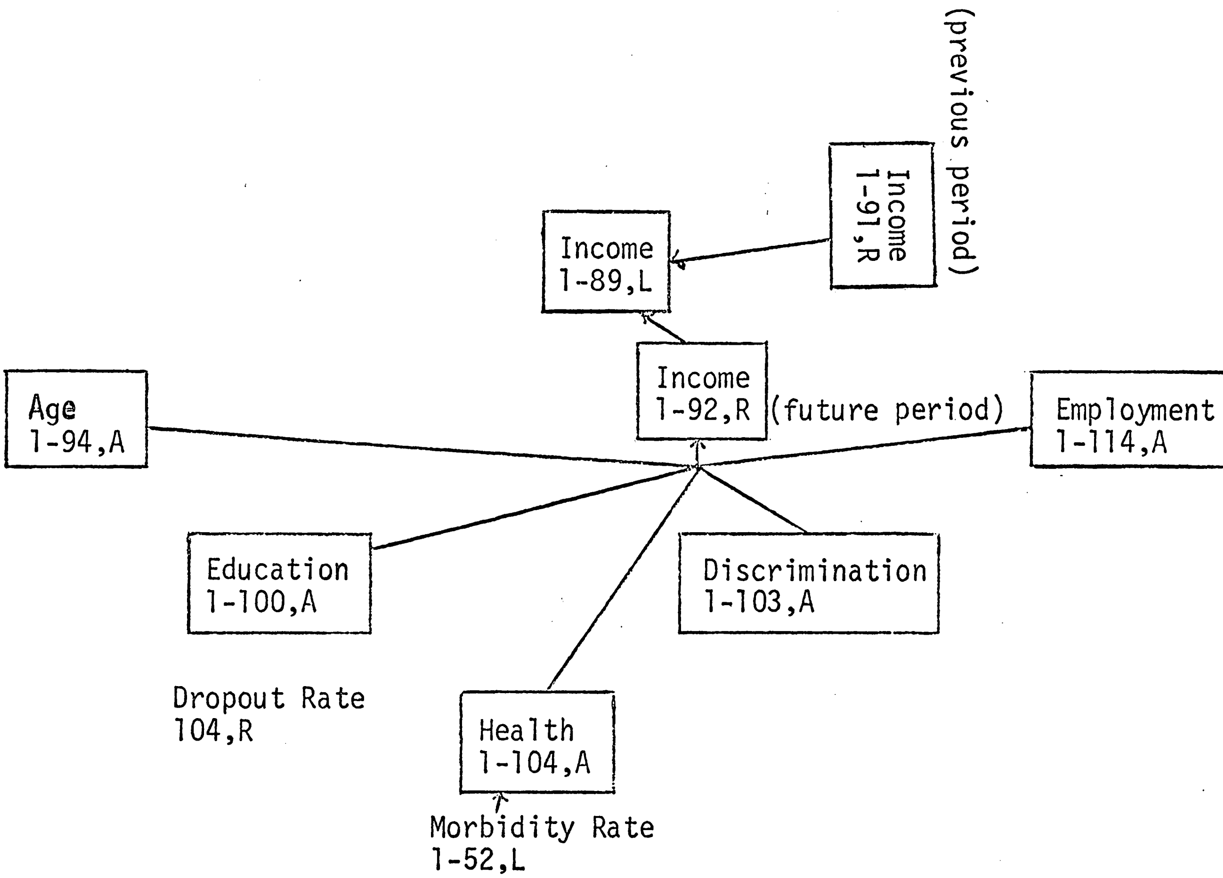

Figure 3-14 -- The Income Component of the System Model

Figure 3-15 -- Income as a Function of Age

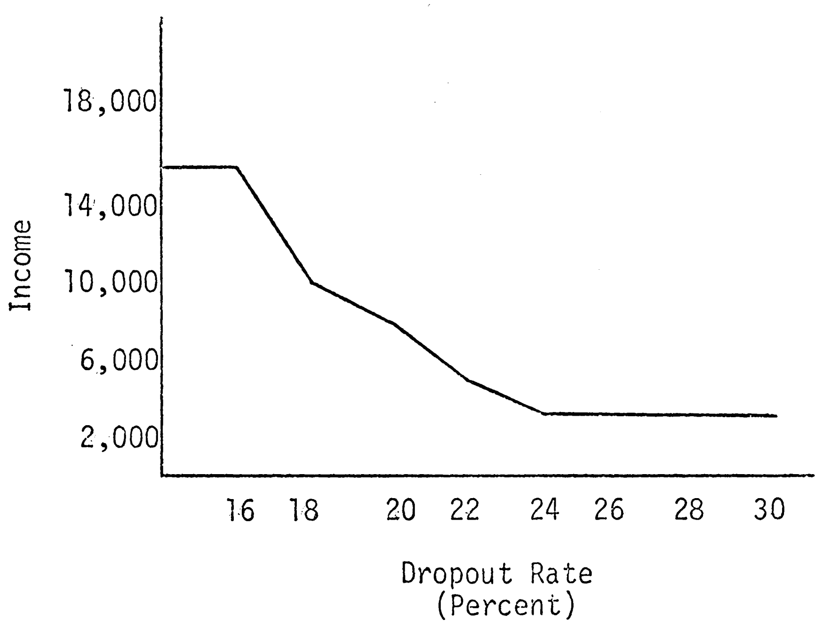

Figure 3-16 -- Income as a Function of the Dropout Rate

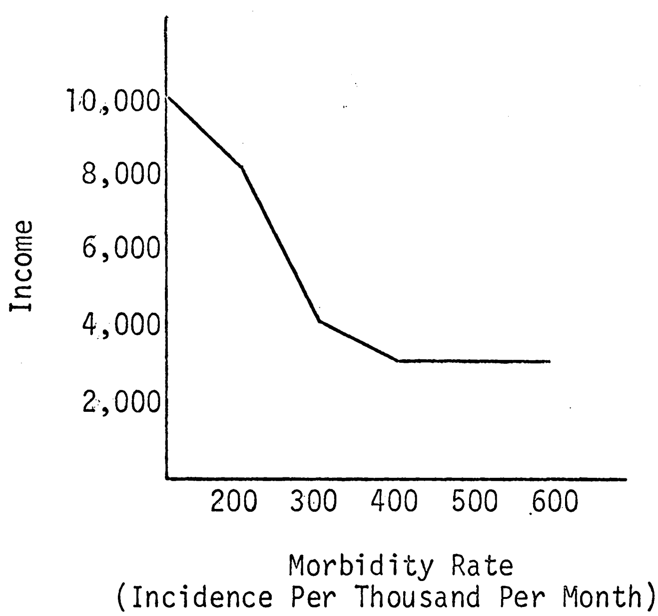

Figure 3-17 -- Income as a Function of the Morbidity Rate

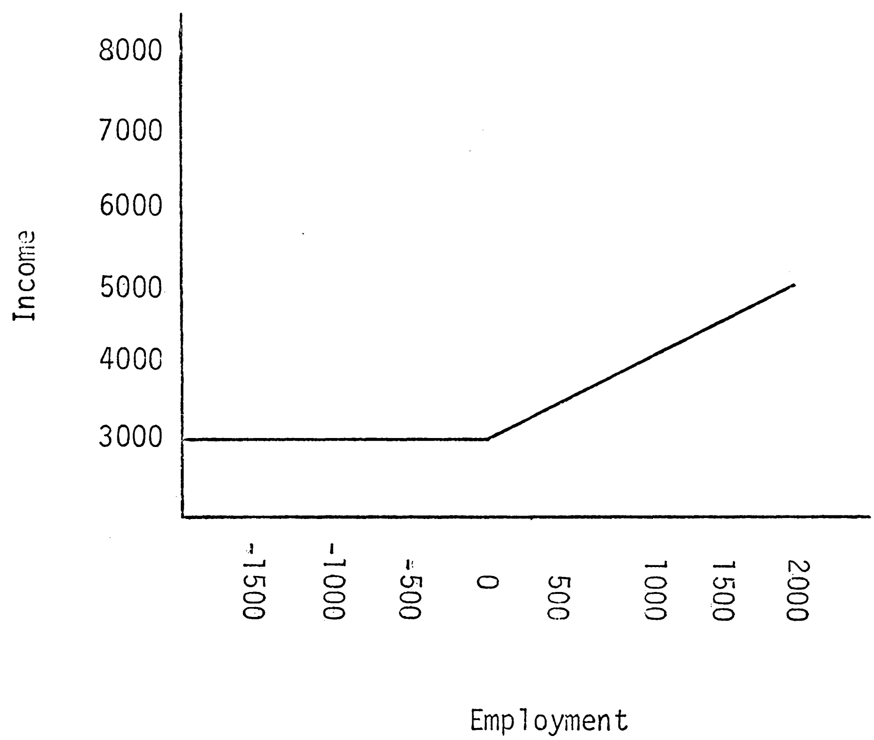

Figure 3-18 -- Income as a Function of Employment

Note: Employment is measured in terms of deviation from the number of jobs available in 1960.

is given in Figure 3-14.

Of the three submodels, income seems to have the greatest potential for social and economic change. The exceedingly high coefficients associated with discrimination and employment - combined with the peculiar nature of their relationship to income, which implies a rapid rise in income with slight decreases in discrimination or small increases in employment - suggests the possibility of socio-economic change and, perhaps, the difficulty of achieving it. The direct feedback loops to education and health serve to accentuate the importance of the income model causing, if unimpeded, circular exponential growth in all three variables: education, health, and income.

1. Age

Studies by Becker,[55] Singell,[56] and Parker and Shaw[57] report the importance of occupational experience (as reflected by age) to income. Becker (1957) argues that work experience is a type of social capital typically rewarded by higher wages. Parker and Shaw's (1968) study of urban labor force characteristics reports that age is nearly half as important as education in determining the income level of the individual. Their analysis indicates that a one-half of one percent increase in income results from a one percent rise in job experience.[58] Similar results were obtained from a regression analysis of model city data. As shown by Figure 3-15, the impact of age tends to increase slowly at first until age 24 is reached; thereafter, it increases in a linear fashion. The negligible occupational experience of the Negro (equivalent to twenty-four years) causes the contribution of Equation 1-94 to be quite low.

INCAGE.K = INCAGP.K * (.05) 1-94,A

Change in INCAGP is introduced through a series of equations that duplicate the probable change in age levels in the study area. A base of 24.1 years is assumed. The rate of change is -.004 per year or -0.95 over a ten year period. Hence the amount of change introduced to INCAGP is anticipated to be small.

2. Education

In contrast to the usual linear relationship between education and income expounded by most theorists, a highly irregular relationship is believed to exist between these variables in Negro low income areas. Research by Harrison[59] in ten ghetto areas in the United States indicates that earnings by Negroes remain constant at a low level until graduation from high school, then increase in a stair-step fashion with increasing years in college. Income rises especially rapidly with increasing years of graduate education. Harrison's findings are reproduced in Figure 3-16.

These results have a profound impact for Equation 1-100, which relates the contribution (.30) of education to income. Change is

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INCED.K = INCEDP.K * (.30) 1-100,A

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introduced to INCEDP through the education submodel; accordingly the relationship is circular and permits exponential growth if unimpeded by independent or internal forces of the type described on pages 16-20.

Thus the base dropout rate (28.8) in the study area need not imply an insurmountable obstacle to income advances. Theoretically, if the dropout rate decreases perceptibly, a marked rise in income should result. This circular-cumulative relationship is impeded in the model, however, by a delay function (SMOOTH) that expresses a time lag to the impact of improved education on cultural attitudes.

3. Health

Similar to health's impact upon education, there seems to be little influence by decreased morbidity upon work productivity. Research by Albert[60] (1967) indicates that very few wages earners from low-income families miss work because of illness. In his sample of seventy-eight families, ninety-three percent reported one or more symptoms of illness per month. Of this percentage, symptoms were recorded for almost two-thirds of the children, one-half of the mothers, but only one-third of the fathers. Only two percent of the total symptoms were translated into requests for physician help or hospitalization.[61] The assumed nature of the relationship between health and income is depicted in Figure 3-17.

Change in Equation 1-104 occurs through INCHTP from data supplied by the health submodel. Because of the peculiar nature of the

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INCHLT.K = INCHTP.K * (-.16) 1-104,A

---

relationship between these variables, given in Figure 3-17, relatively little can be gained from advances in health rates when these rates are between the 300 and 600 range. What advances that do occur are greatest at the 100-300 level. But even these gains, should they occur, are minimized by the comparatively small coefficient in Equation 1-104.

4. Discrimination

Apart from economic conditions, the single greatest effect upon income is racial discrimination. The effects of discrimination are widely documented. Myrdal and Becker, well known for their studies on social and economic discrimination, attribute nearly all the thirty percent to fifty percent salary differential between Negroes and whites to discrimination. Social factors such as age, education, or health are considered of secondary importance.[62] Equation 1-103 reflects this interpretation. It gives a strong emphasis to the overt manifestations

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INCDSM.K = INCDSP.K * (.27) 1-108,A

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of discrimination in terms of salary differentials and labor force participation. It suggests both the potential of change in Negro economic and social conditions with the diminishing influence of this variable and, perhaps, the difficulty of achieving such change.

Significant to this relationship is the declining effect of discrimination. Although statistical analyses of the type performed by Gwartney[63] (1970) suggest that discrimination in the labor market is in fact increasing, the bulk of the descriptive data - including that by Northrup and Rowan[64] and Ross and Hill[65] - indicate a slight relaxation of racial barriers. This, argues Hill, is reflected by the increasing number of Negroes in sales, skilled trades, and the professions. This interpretation is reflected by a steadily decreasing value of INCDSP in Equation 1-108, achieved through a series of rate and level equations.

5. Employment

Equation 1-114 reflects the widely held thesis that economic growth provides the main vehicle for the upward economic and social

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INCEMP.K = INCEP.K * (.51) 1-114,A

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mobility of Negroes. As the supply of jobs grows, a wider distribution of income results. According to Singell, "some people 'spill over' into affluence as income grows."[66] Conversely, as this supply declines, a smaller distribution of income results. Minority groups are particularly affected by the latter. Figure 3-18 depicts this relationship.

The model specifies a steadily increasing employment growth rate in the study area. A series of equations assign an annual increase of 0.029 percent to INCEP in Equation 1-114. Since the relationship between employment and income is strongly linear past the datum level (0.0) in Figure 3-18, a marked improvement in income can be expected. A partial delay function is included to reflect the unequal effect of economic expansion on minority groups. Singell reports that the incidence of poverty for nonwhite families will fall five percent less rapidly than for white families.[67]

Chapter IV

MODEL PROJECTIONS

The projections made in this chapter are derived from a computer simulation model of the circular-cumulative relationship between education, health, and income for a low-income area of Miami, Florida. The format and theoretical underpinnings of the model are based on the writings of Forrester on system dynamics. In a similar fashion, the format and arrangement of the model equation specified in Chapter 3 are structured after those used by Forrester in Urban Dynamics. It should be noted that in programming the model, the DYNAMO language was used. Unlike the more familiar programming languages, as FORTRAN of PL 1, it assumes an initial value for a variable and then works away from that value according to the relationships dictated by the estimating equations. With FORTRAN or PL 1, it is necessary to provide an array of incoming data to estimate the dynamic behavior of systems. This tends to be the greatest difficulty in using these languages in a dynamic context; in contrast, it is DYNAMO's greatest asset and forms the rationale for its use here. Appendix I includes a copy of the program.

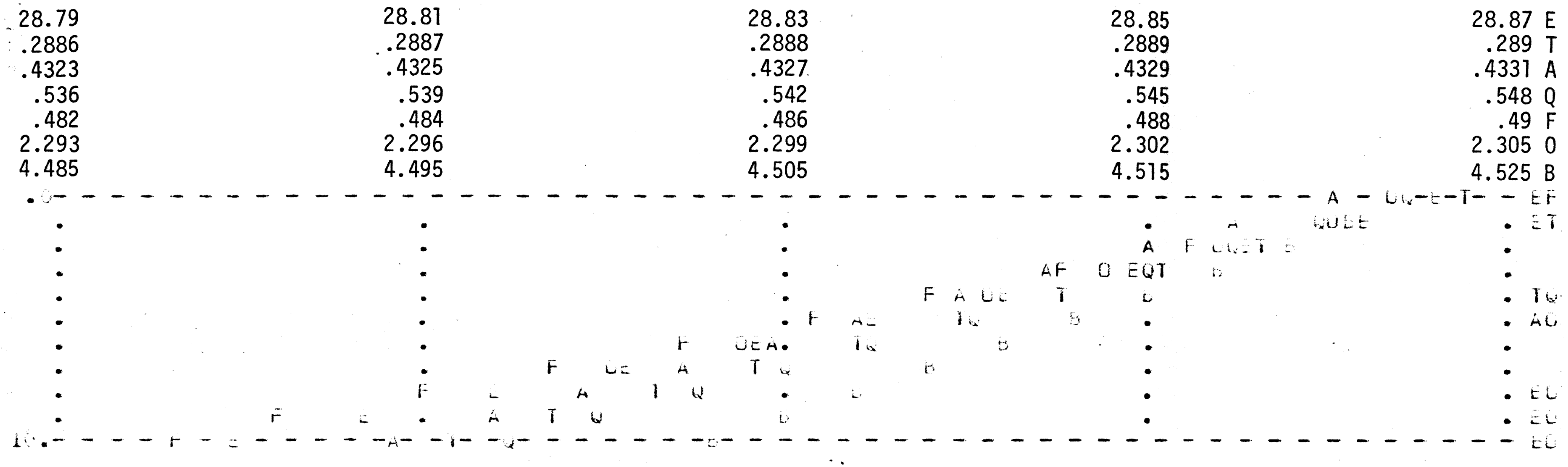
The projections for each of the submodels-education, health and income - are introduced first in this Chapter, then the estimates for the circular-cumulative model.

A. Education

The estimates made by the model for the period 1960-1970 are within three percent of those actually realized in 1970. The model projected this rate as 28.79, whereas the actual rate was 27.75. Calibration of the model to the observed behavior of the dropout rate over the ten-year period accounts for this highly accurate estimate. Similar adjustments were made for the health and income submodels, with generally the same results.

More important, at least theortically, is the actual behavior of the education component over time, in this instance 1960-1970. The behavior of this component - and of the health and income submodels, to be discussed later - is shown by a plot of computer variables and by an enumeration, or table, of these variables.

In Figure 4-1, the behavior of the education submodel is depicted by the movement of supporting and index variables (identified by letter) across the face of the plot from the origin of the simulation at year 1960. The vertical axis in Figure 4-1 indicates time in increments of a year, while the horizontal axis represents the changing numeric quantity of the variables. (Actual numeric values are given at the top of the printout.) From the origin the variables change in value, traversing the graph in a linear or curvilinear fashion, until the horizon year of 1970 is reached. Linear movement is shown by vertical movement across the diagram, as variable E in Figure 4-2. Nonlinear movement - depicted by the nine variables in Figure 4-1 - is represented by curvilinear movement across the plot and may be either positive or negative in direction. If the movement is positive, the variable shifts from left to right on the diagram; if it is negative, then from right to left. This movement,



Dropout Rate = E
Teacher-Student Ratio = T
Teacher Aide-Student Ratio = A
Teacher Quality = Q
Student Body Quality = O
Student Objective Background = B
Student Attitude = P
Morbidity Rate = H

Figure 4-1.--Education Submodel

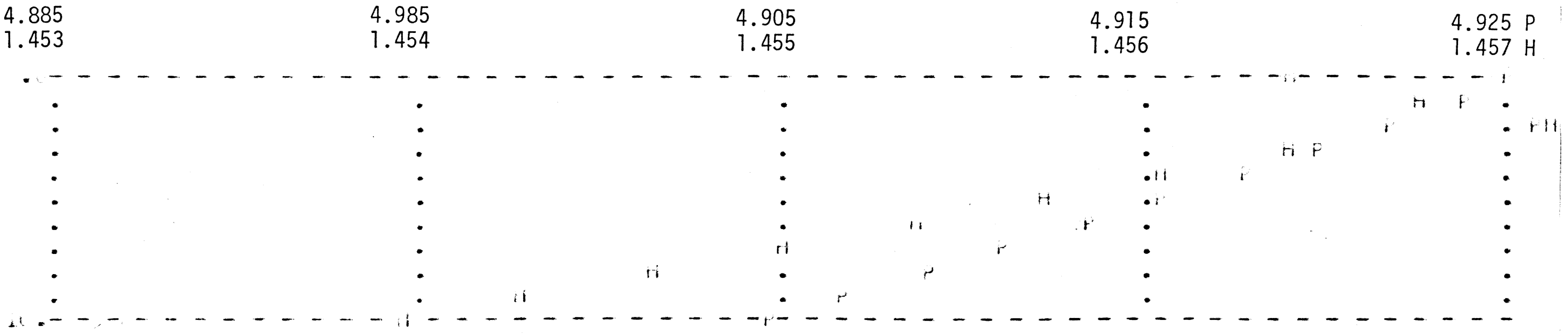


Figure 4 -1.--Continued

Table 4-1.--Education Submodel

Time	Dropout Rate	Teacher-Student Ratio	Teacher-Aide Student Ratio	Teacher Quality	School Facilities	Student Body Quality	Student Objective Background	Student Attitude	Morbidity Rate
1960	28.86	.288	.433	.547	.489	2.30	4.52	4.92	1.45
1961	28.86	.288	.432	.546	.488	2.30	4.52	4.92	1.45
1962	28.86	.288	.432	.545	.488	2.30	4.51	4.92	1.45
1963	28.85	.288	.432	.545	.487	2.30	4.51	4.91	1.45
1964	28.84	.288	.432	.544	.486	2.30	4.51	4.91	1.45
1965	28.83	.288	.432	.543	.486	2.29	4.51	4.91	1.45
1966	28.82	.288	.432	.542	.485	2.29	4.51	4.91	1.45
1967	28.82	.288	.432	.542	.484	2.29	4.50	4.91	1.45
1968	28.81	.288	.432	.541	.483	2.29	4.50	4.90	1.45
1969	28.80	.288	.432	.540	.483	2.29	4.50	4.90	1.45
1970	28.79	.288	.432	.539	.482	2.29	4.50	4.90	1.45

of course, simply reflects the dictates of the estimating equations in the submodel - in this case the educational component. The use of the plot in interpreting system behavior is, then, to readily indicate the general type and direction of movement of component variables.

In Table 4-1, the second of the techniques used to analyze system behavior, the component variables are identified by name at the top of the listing while the time interval (in years) is specified at the left of the tabulation. Actual numeric values, given by variable by year, occupy separate cells of the matrix. Because the table provides an exact indication of component behavior, its primary use is to indicate the precise behavior of the submodel under consideration.

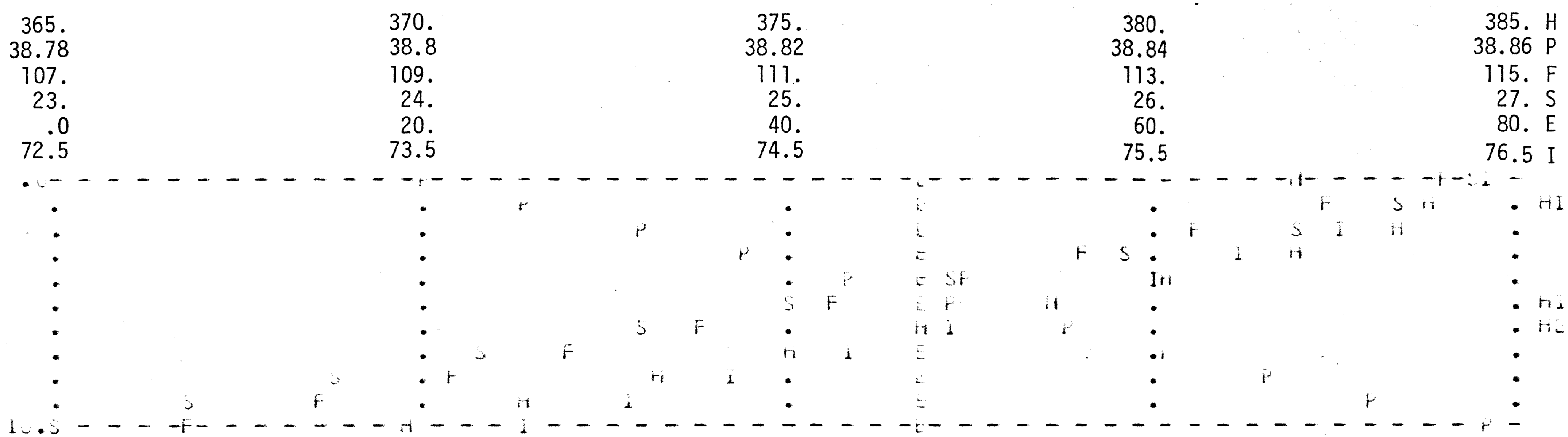
An evaluation of the data contained in the table suggests that the bahavior of the educational component tends to be remarkably stable over time. As previously indicated, the dropout rate remained near an initial level, decreasing only .07 from its original level of 28.866. Apparently the eight contributing variables failed to exert any significant effect upon the index variable, the dropout rate. An examination of the contributing variables in Table 4-1 will confirm this. The student-teacher ratio failed to decrease the dropout rate at all during the period 1960-1970, remaining at its inital value of .288, while the student-teacher ratio declined only .001 from its original value of .433. Nor did the student-teacher quality ratio, which was set to advance quite rapidly during the ten-year period, significantly reduce the dropout rate: It decreased the morbidity level by only .008 (.547 to .539). Neither did the three variables dependent upon the feedback loops from the income submodel - student body quality, student economic background, and student emotional condition - significantly change the dropout rate. Combined, they decreased that rate by only .005, an amount less than that generated by the teacher quality ratio itself. Finally, the effect of health, also dependent upon a feedback structure, was vanishing, remaining at the original level of 1.45. In short, the interdependency embodied in the model structure seemed to inhibit any pronounced advance in system performance. Without a substantial increase in the more strategic system variables (as, for example, student economic background), other variables could not be pulled upward to modify total component behavior.

This failure to produce a more pronounced change in the dropout rate is probably related to (1) the interaction between positive and negative feedback loops in several equations; (2) the curvilinear relationships that exist between the dropout rate and many of the contributing variables; and (3) the slight advances in morbidity and income levels in the other submodels, health and income. With respect to the first of these influences, several of the estimating equations in the educational component were structured so that the function was forced to vary under the dictates of interacting feedback loops. In each of these equations the positive and negative feedback loops were almost exactly balanced. As a result, the numeric value that entered the function was exceedingly low, causing the contribution of that equation to the index variable to be small. The second influence, that of curvilinear relationships, required that fairly significant advances in the contributing variable take place before a corresponding decrease would occur in the dropout rate. These advances were not achieved. Accordingly, even though some of the variables increased in an additive fashion, their eventual effect was minimal. Similar results were generated by the several feedback loops interconnecting the three submodels. An examination of Tables 4-2 and 4-3 will reveal that the rate and amount of change in the health and income components was slight. The absence of sizable change combined with the presence of curvilinear relationships inhibited the potential contribution of feedback structures to the dropout rate.

B. Health

The projections of the morbidity rate over the period 1960-1970 were within one percent of their actual amount, as shown in Table 4-2. In 1970 the morbidity level in the study area was 365, just four points below the estimated value of 369.

The behavior of the health submodel (Plot H, Figure 4-4) was somewhat less fixed than that of the educational component (Plot E, Figure 4-4). Comparison of the two plots will reveal that the curve for the health submodel was somewhat steeper. This indicates that for the health component the extent of system performance was greater and the pattern of that performance less rigid as compared to the education submodel. Nonetheless, this advance must be interpreted solely in terms of the behavior of the education component. The



Morbidity Rate = H
Physician-Patient Ratio = P
Health Facilities = F
Deteriorated Housing = S
Dropout Rate = E
Income = I

Figure 4-2.--Health Submodel

Table 4-2.--Health Submodel

Time	Morbidity Rate	Physician-Patient Ratio	Health Facilities	Deteriorated Housing	Dropout Rate	Income
1960	382	38.8	114	26.8	46.9	76.4
1961	383	38.8	114	26.6	46.9	76.2
1962	383	38.8	113	26.3	46.9	76.0
1963	381	38.8	112	25.9	46.9	75.7
1964	380	38.8	111	25.4	46.9	75.4
1965	378	38.8	111	25.0	46.9	75.2
1966	376	38.8	110	24.5	46.9	74.9
1967	374	38.8	109	24.1	46.9	74.6
1968	373	38.8	109	23.7	46.9	74.3
1969	371	38.8	108	23.3	46.9	74.0
1970	369	38.8	107	23.0	46.9	73.7

absolute decrease in the morbidity rate was in fact quite low. And, for the most part, it can be said that the levels of illness and mortality that characterized the study area at the start of the ten year period were very much the same as that at the end of the period.

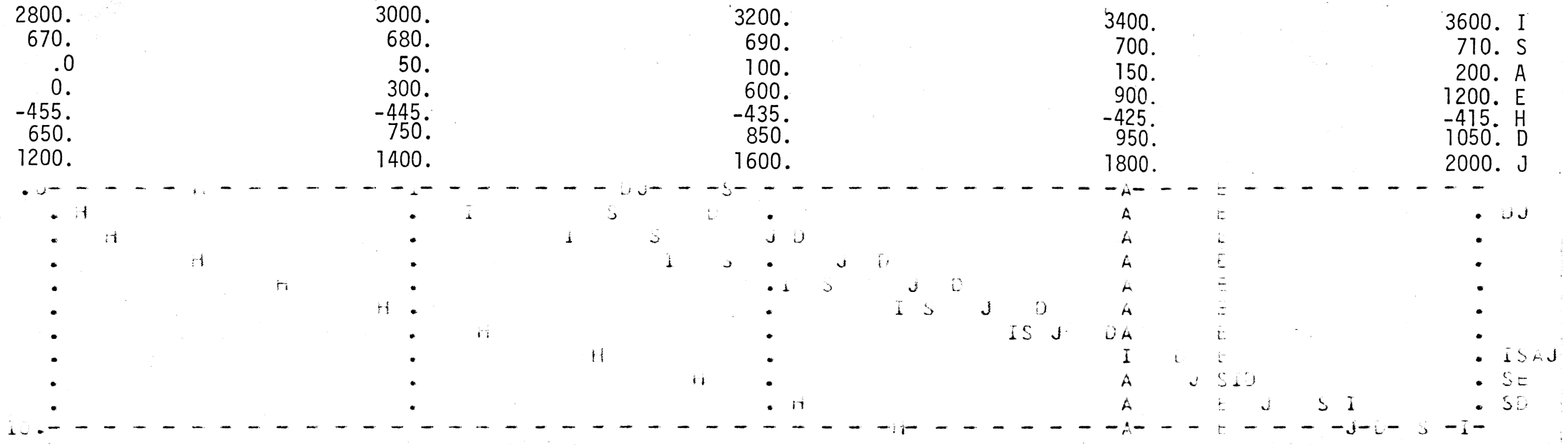
Still, the relative flexibility of this component should be examined. In this submodel the effects of the contributing equations were somewhat greater, for they decreased the morbidity rate from 382 in 1960 to 362 in 1970. Table 4-2 provides numeric equivalents to the plot in Figure 4-2. An examination of this table will disclose that the illness rate declined fairly rapidly at first, then less so in later periods. This reduction must be attributed almost entirely to the effect of two variables, health facilities and housing. The greater number of health facilities available to ghetto residents in the study period (from 10.0 in 1960 to 11.0 in 1970) resulted in a six point reduction in the morbidity level. Similarly, the decrease in the number of deteriorated housing units between 1960 and 1970 (from 2,100 units to 1,530 units), accounted for a 3.8 point reduction in the illness rate. Their combined effect, then, bettered health levels by almost twelve points over the period 1960-1970. The sharp decline in the ghetto illness level in 1971 and 1972, shown by the sharply curvilinear path of variable H in Figure 4-4, resulted from the revision of equations 1-68 and 1-75 to reflect an instantaneous decline in morbidity.

The effect of the remaining variables was negligible. The first of these, the physician-patient ratio, in fact deteriorated during this period, dropping from .72 per thousand to .71 per thousand. Apparently the population growth rate increased at a somewhat faster pace than did the physician growth rate. Nor did the educational variable have an appreciable effect on morbidity rates. Although its estimating equations provided little change, what little that did occur was attenuated by the function in the model, which introduced a first-order delay into the feedback loop connecting the two models. Finally, the impact of the income variable was low. That feedback loop generated only a 2.70 decrease in the illness rate, from an initial contribution of 76.4 in the first simulation to a contribution of 73.7 in the second.

Thus, as before, the presence of the two feedback loops failed to exert an appreciable influence. Each was attenuated by their curvilinear relationship to the health variables and by their relatively scant advances in internal value. Lacking a circular-cumulative advance in certain variables, the health component was constrained in its development, depending entirely on the internally generated gains of its housing and facilities equations. Apparently advances of the latter type are not fully adequate to create a large downward movement in illness rates.

C. Income

The projections of the income level made by the model were comparable in accuracy to the estimates made in the education and health models, being within ten percent of the actual amount in 1970. Table 4-3 gives the numerical values for the five equations in the income model; Figure 4-3 provides a plot of their distribution.



Income = I (constant dollars)
Social Capital = S
Age = A
Dropout Rate = E
Morbidity Rate = H
Discrimination = D
Employment = J

Figure 4-3.--Income Submodel

Table 4-3.--Income Submodel

Time	Income	Age	Dropout Rate	Morbidity Rate	Discrimination	Employment
1960	3000	150	990	-451	810	1530
1961	3028	150	990	-454	834	1565
1962	3085	150	990	-453	857	1602
1963	3146	150	990	-451	880	1639
1964	3208	150	990	-448	902	1677
1965	3272	150	990	-445	924	1716
1966	3335	150	990	-442	945	1757
1967	3399	150	990	-439	965	1798
1968	3463	150	990	-437	985	1840
1969	3528	150	990	-434	1004	1884
1970	3593	150	990	-431	1022	1928

The income component seems to have had the greatest flexibility and largest gains of the three submodels over time. As a result of reduced morbidity and discrimination and increased employment, there was a fairly large rise in income, from $3,000 in 1960 to $3,593 in 1970 for ghetto families. (Plot I in Figure 4-4 shows this increase to be sharply curvilinear but tending to flatten toward the end of the study period: Income tends to increase fairly rapidly at first but then less rapidly.) Although this figure is $600 below the actual level of income for the study area in 1970, when adjustment is made for inflation (which averaged over fifteen percent for the decade in the Miami area), the $4,200 figure is reached.

Of the three variables-morbidity, discrimination, and employment - the principal contributors to increased income were (reduced) discrimination and (rising) employment. Their effect was to steepen the plot of Curve I in Figure 4-4. This conforms to post-Kaynesian macro theory, which asserts that income is inversely associated with unemployment but directly associated with advancing investment-savings and growth ratios.[1] Discrimination, which was stipulated to have decreased by one index point (the function in Equation 1-108 received its value in terms of a deviation from a datum level, set at 0) over the ten year period, advanced the 1960 income level by $212.

Employment, however, provided the greatest absolute contribution to income, improving the 1960 income level by nearly $400. The employment equations, it will be recalled, were formulated to reflect an expanding job market. Curves D and J, respectively, identify the discrimination and employment equations in Figure 4-3; note that they closely parallel one another, indicating that the relative contribution of each to the level is nearly idential, and that discrimination steepens somewhat toward the horizon year; this suggests that the effects of job discrimination are lessening even more substantially toward the end of this period. Finally the effect of the three social capital variables - age, education, and health - contributed an extra $20 to income in 1970. An examination of Table 4-3 will indicate that both age and education remained at their 1960 levels; only health, which contributed an additional $20, evidenced improvement during this period. The effects of education upon income were ameliorated by a first order exponential delay (SMOOTH) in the model; the nature of the curvilinear relationship between age and income stymied a contribution by that equation to income.

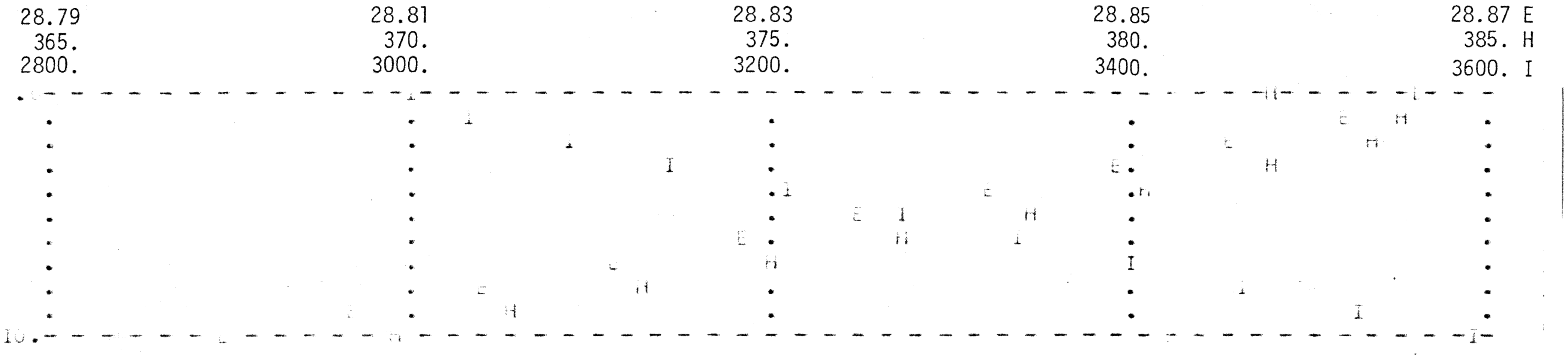
The near vanishing impact of the three social variables--age, education, health--seems to confirm the argument advanced by Singell,[2] Becker,[3] and Mydral[4] that economic advances for low income minority groups must come from other, primarily economic, influences. Significant advances in health and education, they contend, will have little effect on income when discriminatory job barriers exist or when the labor market is experiencing decline or is stagnant. Nor will these variables have an appreciable effect on income when the job market is experiencing rapid advances--as in the late sixties--since the impact of discrimination is such that many jobs are denied even highly skilled Negroes. Seemingly this argument is buttressed by the advances generated by reduced discrimination and an expanding employment market.

It suggests that resources may better be used to reduce the legal-institutional barriers to employment.

D. Summary

Upon aggregations these results, it appears that the study area was characterized by a high degree of stability. Little or nominal change was projected for the educational component, and only moderate change from the health and income submodels. This conforms to the actual situation in the study area during 1960-1970. Little or no upward growth from its low equilibrium position was apparent during that period. Indeed, some observers have said that the area actually declined in terms of performance toward reaching broadly-held community goals-improved education, better economic conditions, and improved health levels. The general trend of the three components - education, health, and income - is given in Figure 4-4. Note the nonlinear advances of each and the gradualism of their increase. Actual numerical values are presented in Table 4-4. These projections, then, partially support Mydral's theories of circular-causation and circular-cumulative advance for low-income areas.

It will be recalled (pages 11-13) that intrinsic to the process of circular causality is an inextricable relationship of cause and effect that effectively operates to imprison the social or economic system in its own shortcomings. The idea is that a given effect acts as a cause to a substantially similar effect. As we have seen, the Model City area seemed to advance little in the study period, in fact remaining in a state of near equilibrium. Effects produced by the



Dropout Rate = E
Morbidity Rate = H
Income = I

Figure 4-4.--System Model - Education, Health, Income

Table 4-4.--System Model-Education, Health, Income

Time	Dropout Rate	Morbidity Rate	Income
1960	28.86	382.0	3000
1961	28.86	383.89	3028
1962	28.85	383.32	3085
1963	28.84	381.97	3146
1964	28.84	380.29	3208
1965	28.83	378.53	3272
1966	28.82	376.76	3335
1967	28.82	374.99	3399
1968	28.81	373.23	3463
1969	28.80	371.47	3528
1970	28.79	369.72	3593

contributing variables to health, education, and income seemed negligible or nonexistent in the positive direction. Hence the conditions of the study area remained at initial levels, to produce generally similar effects.

The concept of circular-cumulative advance was only partly confirmed in this initial simulation. Change in one factor, say health, did not produce changes of an additive type in other, related variables as suggested by a theory. There seemed to be three reasons for this First, in some equations the values entered into the function were dependent upon the performance of linked negative and positive feedback loops. Typically these loops were almost exactly balanced, so that the magnitude of the numeric change was never great. Second, the curvilinear relationships common to many variables suppressed a cumulative advance in the numeric quantities of these variables. Third, the several feedback loops interconnecting the three model components failed to generate cumulative change. According to Myrdal and other developmental economists, movement out of a low equilibrium condition - such as that characterized by an urban ghetto - cannot take place without the exponential growth made possible by these loops. Exponential delays of the type generated by the SMOOTH function exaberated this circumstance.*

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* This does not entirely invalidate Myrdal's cumulative theory, though. It may well be that very substantial advances in one component are necessary to push related variables past a cumulative threshold. Should this happen, advances of an additive nature may eventually develop.

Chapter V

MODEL PROJECTIONS - TRANSPORTATION

The orignial formulation of the model presupposed that movement between ghetto residences and desired facilities was generally slow and dependent upon transit. Modifications are now introduced that suggest an increasing ease and rapidity of such movement. These modifications correspond to improvements in accessibility made possible by a rapid transit system. Such a system actually is contemplated for the Miami-Dade County area in the near future.[1] Transportation modifications are estimated to be equivalent to a forty percent reduction in travel time over the previous system. For the sake of simplicity, these reductions are assumed to occur in all directions.

I. Model Equations (Revised)

A. Education

The effects of busing upon student academic performance are suggested in the following equation. Coleman reports (pages 39-43) that of all the attributes associated with the educational process, aside

DROPSQ.K - DRSQ.K * (.020) where DRSQ.K - 20.0 1-36,A

from those of student background and personality, the achievement of minority group children is mainly contingent upon the backgrounds, aspirations, and, perhaps most important, work habits of fellow students. Equation 1-36 presumes that exposure to the different values and work patterns of whites does in fact create a better attitude toward education in minority children. This assumption is expresses as a dropout value of 20.0 in DRSQ.K, which corresponds to the dropout rate recorded in suburban Miami schools.

B. Health

Increased accessibility is believed to improve the availability of physicians and health facilities in suburban areas to ghetto residents. This is reflected by an increased accessibility value in Equations 1-56 and 1-68, discussed on pages 51 and 52. The value of HPHRTP in Equation 1-56 is now set at 1.10 to correspond with a total urban accessibility to physicians, while HFACSP in Equation 1-68 is set at 280 to achieve the same relationship for health facilities. The improved accessibility expressed in these equations is believed to result in a significant reduction of morbidity rates.

Empirical justification for this effect - to buttress the descriptive evidence of such a relationship by Salisbury and Robinson[2] and the statistical analyses of Hodges[3] and Lubin[4] - comes from the (high) usage rates of a recently established health clinic at the center of the Model City area. Significantly, these rates - and the evidence reported in other studies - correspond to the theories of physician (and facilities) utilization developed by Garrison[5] in 1959. According to Garrison, reductions in transportation cost should both increase the availability of physicians (and facilities) and decrease the cost of medical treatment. He explains the latter thusly:

"If the amount of services increases faster than demand in a given area (as it should through transportation expanding the service zone for physicians) the price will fall."[6]

C. Income

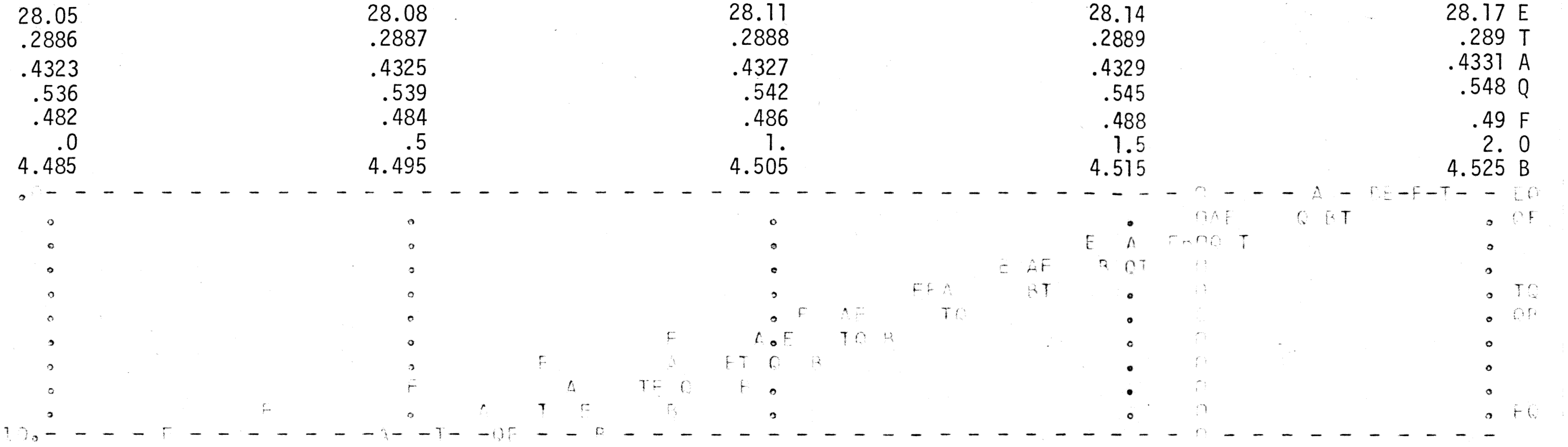
Mass transit is assumed to have relatively little effect in improving income levels. As suggested by Kalicheck[7] and others, a fixed-route transit system is simply unable to provide the ready, convenient movement to suburban manufacturing and tourist trade industries required by central city workers. This circumstance is repeated for the study area. The dispersal of employment throughout the Miami area makes travel for ghetto residents dependent on transit very difficult, requiring multiple transfers and a considerable amount of time - often an hour or more. Model City residents apparently see both as significant obstacles. Many elect to work in close-in jobs.[8] The reduced regression coefficient, from .51 to .49, in Equation 1-114 expresses this reluctance to travel long distances.* The difference in coefficient value is assigned to Equation 1-108, which, in effect, reflects a type of economic discrimination.

*The relatively large number of families with cars (.80 per family) ameliorates a more sizable reduction in this coefficient.

II. Model Projections

A. Education

Modification of the initial computer program to reflect on integrated school environment produced almost no change in the behavior of the educational model. Applying this modification, the dropout rate was decreased by only 0.68 from its original rate of 28.6 - an insignficant amount given the magnitude of most busing programs. The fixity of the education submodel is documented by the plots for general component behavior (Figures 4-4 and 5-4) and for the educational component itself (Figures 4-1 and 5-1). Comparison of the curves for education (designated E) in Figures 4-4 and 5-4 will show that the general character of the educational component remained unchanged throughout both simulations. The shift to the right in Curve E in Figure 5-4 simply reflects the reduced dropout rate, not a major change in component behavior. The stability of the education submodel is, perhaps, even more perceptible in Figures 4-1 and 5-1, which depict the behavior of each of the contributory equations - the student-teacher aide ratio, etc. - in the education model. With the exception of Curves O, H, and P, the variable plots are identical in both diagrams. Curves H and P (health and student emotional background) evidence a different arrangement in Figures 4-1 and 5-1, but in terms of absolute change the amount is minimal. According to Table 5-1, which specifies the precise value of the education equations, health (H) advanced just .01 percent and student attitude (P) just .02 percent in the second simulation. Only Equation 1-39, student objective background (O),



Dropout Rate = E
Teacher-Student Ratio = T
Teacher Aide-Student Ratio = A
Teacher Quality = Q

Figure 5-1.--Education Submodel with Transportation Modifications

Student Body Quality = O
Student Objective Background = B
Student Attitude = P
Morbidity Rate = H

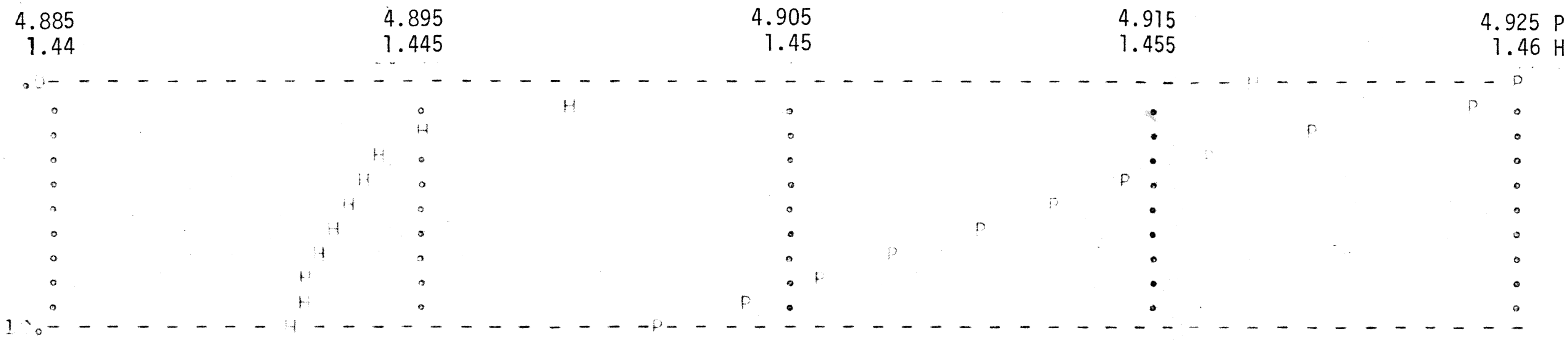


Figure 5-1.--Continued

Table 5-1.--Education Submodel with Transportation Modifications

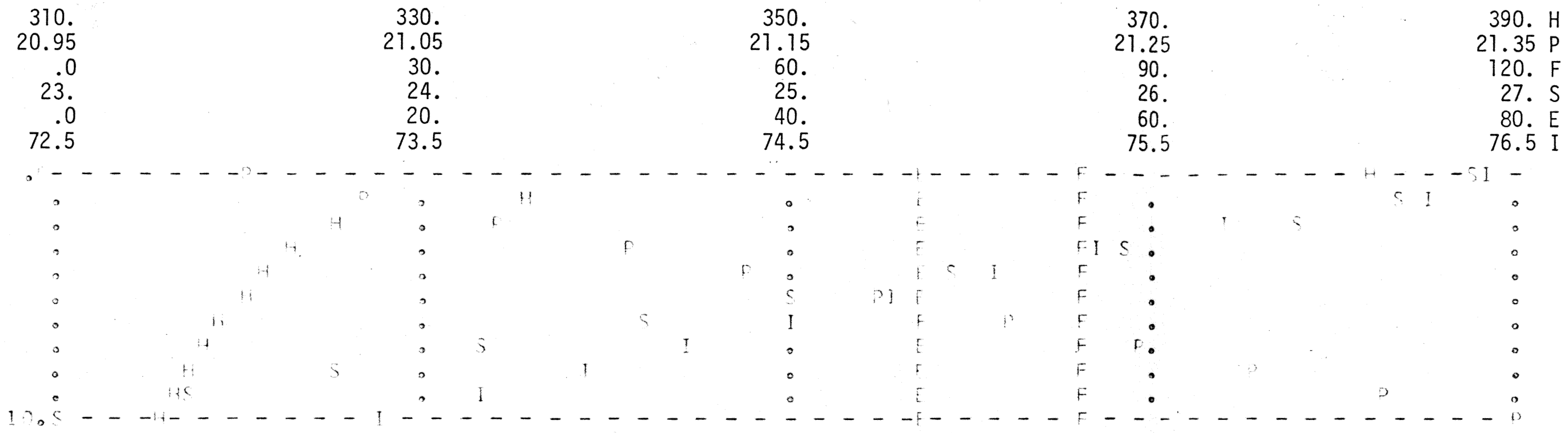
Time	Dropout Rate	Teacher-Student Ratio	Teacher Aide Student Ratio	Teacher Quality	School Facilities	Student Body Quality	Student Objective Background	Student Attitude	Morbidity Rate
1960	28.16	.288	.433	.547	.489	1.60	4.52	4.92	1.45
1961	28.14	.288	.482	.546	.488	1.60	4.52	4.92	1.44
1962	28.13	.288	.432	.545	.488	1.60	4.51	4.91	1.44
1963	28.12	.288	.432	.545	.487	1.60	4.51	4.91	1.44
1964	28.12	.288	.432	.544	.486	1.60	4.51	4.91	1.44
1965	28.11	.288	.432	.543	.486	1.60	4.51	4.91	1.44
1966	28.11	.288	.432	.542	.485	1.60	4.50	4.91	1.44
1967	28.10	.288	.432	.542	.484	1.60	4.50	4.90	1.44
1968	28.10	.288	.432	.541	.483	1.60	4.50	4.90	1.44
1969	28.09	.288	.432	.540	.483	1.60	4.50	4.90	1.44
1970	28.08	.288	.432	.539	.482	1.60	4.50	4.90	1.44

demonstrated a real change between the two simulations, given in Table 5-1, decreasing from 2.29 percent to 1.60 percent. The abruptness and magnitude of that modification is reflected in Curve 0 in Figure 5-1, which is linear. This contrasts with the generally curvilinear pattern of Curve 0 in Figure 4-1. Apparently the changes emanating from Equation 1-39 were incapable of forcing an upward movement in the educational component as a whole.

Because of the generally small change in the dropout rate, the feedback relationships between the three models failed to elicit exponential growth. The contribution of the educational component to these models, given in Equations 1-40 and 1-100, actually failed to generate any improvement in the health and income components. Examination of Tables 5-2 and 5-3 will reveal that the education variable remained at the 46.9 level in the health submodel and at the 990.0 level in the income submodel. Delay functions and curvilinear relationships of the type described on page 85 impeded the effects of these equations.

B. Health

The increased availability of physicians and health facilities made possible by transportation improvements produced, in contrast, a fairly sizable reduction of the morbidity rate. This rate was reduced from 382.0 in the original simulation to 315.0 in the revised model, a difference of some sixty-one points. The magnitude of this change is suggested by a comparison of Figure 4-4 with Figure 5-4. In Figure 5-4 the plot of the index variable for health (H) is displaced toward the



Morbidity Rate =H
Physician-Patient Ratio = P
Health Facilities =F
Deteriorated Housing = S
Dropout Rate = E
Income = I

Figure 5-2.--Health Submodel with Transportation Modifications

Table 5-2.--Health Submodel with Transportation Modifications

Time	Morbidity Rate	Physician-Patient Ratio	Health Facilities	Deteriorated Housing	Dropout Rate	Income
1960	302	21.0	84	26.8	46.9	76.4
1961	335	21.0	84	26.6	46.9	76.2
1962	325	2.10	84	26.3	46.9	75.6
1963	322	21.1	84	25.9	46.9	75.3
1964	321	21.1	84	25.4	46.9	75.0
1965	320	21.1	84	25.0	46.9	74.7
1966	319	21.2	84	24.5	46.9	74.5
1967	318	21.2	84	24.1	46.9	74.2
1968	317	21.2	84	23.7	46.9	73.9
1969	316	21.3	84	23.2	46.9	73.6
1970	315	21.3	84	23.0	46.9	73.3

left of the diagram and is only slightly curvilinear in its advance. In contrast, in Figure 4-4 the path of variable H is strongly curvilinear. An examination of Figure 5-4 will also reveal that the reduction in the morbidity rate was greatest in years 1961 and 1962, depicted by the sharp displacement of curve H to the left, reflecting the assumed equivalency of the Model City health levels to corresponding levels of physician and health facility availability in the suburban areas of Miami. Once past these periods, however, the illness rate declined less rapidly (indicated by the near linear track of variable H), although always in a positive fashion. Apparently the effects of accessibility are greatest initially; thereafter, they taper off as people have less need of health services.

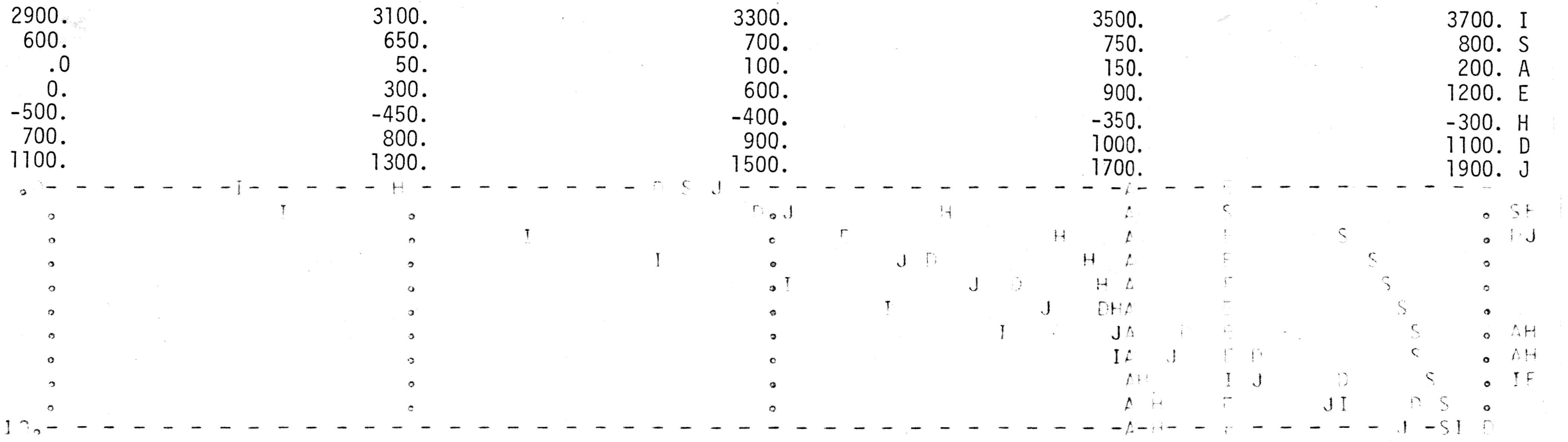
The impact of improved accessibility to physicians and medical facilities, given in Equations 1-56 and 1-68, upon the morbidity rate is suggested by the changed pattern of Curves P (physician-patient ratio) and F (health facilities) in Figure 5-2. Comparison of that diagram with Figure 4-2, the plot of the health component for the initial simulation, will reveal that Curve P in Figure 5-2 is not nearly as steep as Curve P in Figure 4-2. This suggests that the physician-patient ratio is more effective in reducing the morbidity rate in the revised (second) simulation. A comparison of these diagrams for curve F will disclose an even more pronounced variation; in Figure 4-2 curve F is generally curvilinear, whereas the same curve in Figure 5-2 is entirely linear. The linear track of variable F in Figure 5-2 identifies a very substantial advance in the effect of medical facilities upon the morbidity rate. Indeed, the principal contribution to the reduction in that rate is generated from Equation 1-68, which describes the influence of health facilities upon the index variable for health.

This reduction in the morbidity rate affected the education and income submodel differently. In the former, the contribution of health to education, given as the health variable in Table 5-1, was slight, causing only a 0.01 percent reduction in the dropout rate. In the latter, its effect was much more pronounced. Improved health generated a $106 increase in income, an advance of nearly $86 over the original simulation. An examination of Figure 5-3 will reveal that much of this advance was produced during the early and middle periods (1960-1964 of the simulation. After 1964 the contribution of Equation 1-104 was less noticeable but still significant, as shown by the sharply curvilinear path of Curve H (health) in Figure 5-3. Seemingly, then, the effects of health are most pronounced as incomes rise and as the urban ghetto moves out of its low-equilbrium state.

The sharp increase in income from the reduction in the morbidity rate was the first instance of a strong exponential relationship between two submodels. It gives partial support to Mydral's hypothesis that advances in circular, low-equilibrium relationships can only be generated from sizable and across-the-board improvements in linked variables.

C. Income

Income was little affected by the revisions to the equations estimating employment and discrimination in the model. The fixity of the curves for income (I) in Figures 4-4 and 5-4 confirms the absence



Income = I (constant dollars)
Social Capital = S
Age = A
Dropout Rate = E
Morbidity Rate = H
Discrimination = D
Employment = J

Figure 5-3.--Income Submodel with Transportation Modifications

Table 5-3.--Income Submodel with Transportation Modifications

Time	Income	Age	Dropout Rate	Morbidity Rate	Discrimination	Employment
1960	3000	150	990	-451	870	1470
1961	3028	150	990	-376	896	1504
1962	3163	150	990	-360	921	1539
1963	3239	150	990	-355	946	1515
1964	3305	150	990	-353	969	1611
1965	3368	150	990	-352	992	1649
1966	3430	150	990	-350	1015	1688
1967	3492	150	990	-349	1037	1727
1968	3555	150	990	-347	1058	1768
1969	3618	150	990	346	1078	1810
1970	3682	150	990	-345	1098	1852

of significant improvement. To a very large extent, of course, this reflects the minor change in the conditions replicated by the two equations. Nonetheless it does seem that Kalichek's thesis regarding rapid transit and minority employment is at least partly valid.

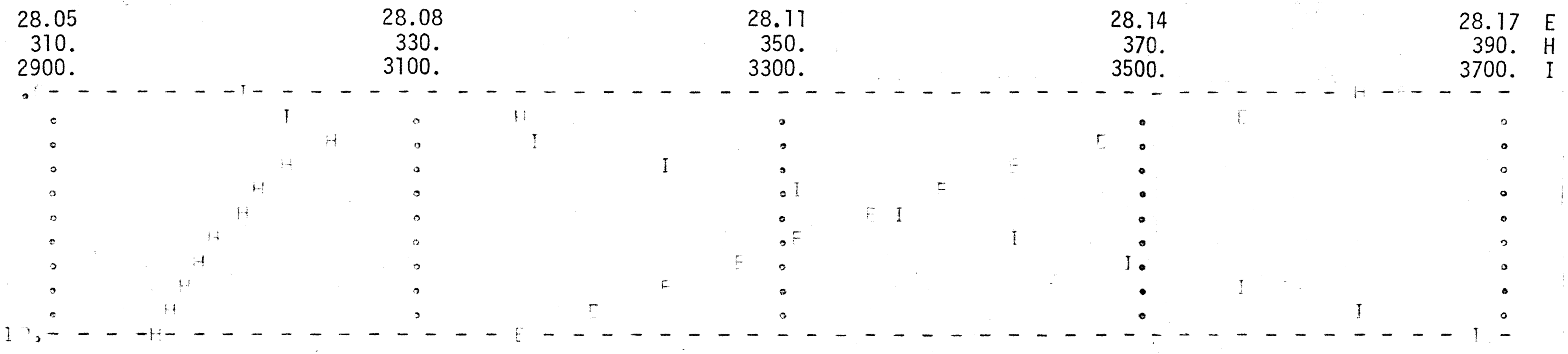
A comparison of Figures 4-3 and 5-3 will disclose the main apparent reasons for the small advance in the income level with modifications in transportation. Two of the contributing equations (age and education) remained unchanged, as indicated by the linear orientation of Curves A (age) and E (education). More important, of the two equations that were altered - employment and discrimination - the magnitude of the resulting change was only moderate. The very slight displacement from the pattern of the original simulation, given in Figure 4-3, underscores the relative absence of change in both employment and discrimination. Only health, described by Curve H in Figure 5-3, substantially improved income, advancing that level some $86. The strongly curvilinear path of health in Figure 5-3, which contrasts sharply with the generally curvilinear path of that variable in Figure 4-3, suggests that the contribution by health to income was greatest during the initial rounds of the simulation, from 1960 to 1963.

Because of the relatively small change in the income level, the feedback relationships with the health submodel were little affected. According to Table 5-2, the health variable declined only 2.7 points, (76.4 to 73.7) in the second simulation. Hence change in the health submodel was slight. The fixity of income (Curve I) in Figures 4-2 and 5-2 confirms the absence of significant change. Modification in the education component was obviated by the changed format of Equation 1-36 which set income to an artifically high level in an attempt to stimulate the effect of middle class conditions upon Negro school children. (pages 86-87). Little change resulted from this modification, it will be recalled.

D. Summary

With the exception of the health component, which decreased some sixty-one points in the revised simulation, changes in model accessibility produced relatively few advances in total system performance. The dropout rate and income level remained near their original (1960) state. Figure 4-4 depicts the general trend of system behavior prior to the modification of the model; Figure 5-4 shows the impact of transportation improvements upon this behavior. Note the general stability of the education and income components, evidenced by the generally similar track of variables E (education), and I (income) in the two diagrams, and the absence of system fluctuations from the curvilinear movement of the index variables. In a fully dynamic model, such as Forrester's <u>World Dynamics</u>, the path of system variables are often oscillatory or highly skewed. Only the health component (H) evidenced marked changed, indicated by its transition from a strongly curvilinear behavior in Figure 4-4 to a nearly linear movement toward the end of the study period in Figure 5-4.

It is most significant that of the three submodels to undergo a revision of their estimating equations, that the greatest modification in these equations occurred in the health component and that the health



Dropout Rate = E
Morbidity Rate = R
Income = I

Figure 5-4.--System Model--Education, Health, Income--with Transportation Modifications

Table 5-4.--System Model - Education, Health, Income with Transportation Modifications

Time	Dropout Rate	Morbidity Rate	Income
1960	28.16	382.0	3000
1961	28.14	335.49	3028
1962	28.13	325.44	3163
1963	28.12	322.46	3239
1964	28.12	321.06	3305
1965	28.11	320.06	3368
1966	28.11	319.17	3430
1967	28.10	318.31	3492
1968	28.10	317.48	3555
1969	28.09	316.66	3618
1970	28.08	315.86	3682

component experienced the greatest advance in system performance during 1960-1970. Figure 5-4 shows this improvement (Curve H) to be first strongly curvilinear, then almost linear in the later periods (1963-1970) of the simulation. The figures for the health variable in Table 5-4 will confirm the abruptness and magnitude of the change in this component. In this submodel the two equations that an important contributory effect upon the morbidity rate - indicated by the high coefficients assigned to these equations - were significantly altered: Equations 1-56 and 1-68, used to estimate the effect of physician and medical facility availability upon the ghetto population, were reset to approximate an accessibility to these factors in terms of an efficient transit system. As a result of this change, a marked downward movement in the morbility rate transpired which, in turn, activated a positive feedback loop between the health and income submodels. It will be recalled that the health variable of the income component was instrumental in forcing the upward movement in the income level between 1960-1970. That change was brought about in the previously low-equilibrium condition of the model suggests, first, that system change can only come about through the revision of strategic variables, and, second, that the change in these variables must be large and operative over a long period of time. Equations 1-56 and 1-68 were both modified to replicate an ideal circumstance and were both forced to operate for the ten-year period of the simulation.

Seemingly, then, improvements in transportation do have a measurable effect upon system performance when there is a strong dependent relationship between the strategic variables of the system and accessibility. This effect is indirect, however, often expressed through the increased availability of an element critical to system behavior. It need hardly be emphasized that only certain of these variables are greatly dependent upon transportation for their effect. Student psychological attitude, for example, which is vital to academic performance, is not related in any significant way to the benefits of transportation. In fact, most strategic variables are not dependent upon transportation to any great degree. Accordingly, the contribution of transportation to education, health, and income must be viewed in limited terms - as a catalyst or precondition to system change but certainly not as the critical element of that change.

Chapter VI

CONCLUSIONS, MODEL EVALUATION, FUTURE RESEARCH

From the preceding analyses a number of tentative conclusions, some already mentioned, have emerged concerning the structure and dynamics of system behavior in a ghetto area. To a very large extent, they confirm Myrdal's theories of circular causation and circular cumulative causation.

Conclusions

The stability of the low-income ghetto is readily apparent. System behavior over the ten year period 1960-1970 failed to show a significant advance in school attendance, morbidity, or income. Nor did system behavior evidence oscillatory patterns such as occur in a fully dynamic and interdependent system of the kind developed by Meadows[1] and Forrester. Neither did the simulation model evidence fluctuation about a mean equilibrium position such as might have occurred with the balanced interaction of positive and negative feedback loops interconnecting the three model components - education, health, and income. Rather, there was a general fixity of model behavior, as indicated by the similarity of the variable curves in Figures 4 -4 and 5 -4. Apparently Myrdal's theory concerning the permanence of ghetto areas (pages 11-12) is substantially correct. The structure and processes of the ghetto tend to remain unchanged over time. The circularity of factors characteristic of such areas tend to preserve the <u>status quo</u>: a given effect acts as a cause to a substantially similar effect.

The impact of change upon the system was also confirmed as slight. In this analysis, change was introduced through a simulated improvement in transportation. With the single exception of morbidity rates, which declined some sixty-one points, little change in system performance was evident. According to Myrdal, "If any attempt is made to life any part of this mesh of interlocking circles (system), there is usually a downward pull so that any sustained progress becomes impossible."[2] This circumstance applies to the effects generated by transportation in this simulation. As we have seen, improved accessibility by itself cannot push the total system toward a higher level of performance. The circularity of other factors -- health, education, and low income -- inhibits the (positive) effects of a single system element.

While the inability of transportation to produce system change supports Myrdal's theories of circular-causation and low-equilibrium permanence, it nonetheless requires a partial revision of his theory concerning circular-cumulative advance. According to Myrdal, change in one factor in an interdependent system results in "consequential impulses, which in turn give rise to repercussions, magnifying the initial change."[3] The results of the second simulation indicate that circular change does not always lead to a proportional advance in other variables. In fact, as we have seen, it may not produce any change at all. This results from three programming structures in the model: Curvilinear and delay relationships and (small) equation coefficients. The curvilinear relationships peculiar to most variables (pages 27-65) act to minimize the accumulative advance generated by linked variables.

Under this type of relationship, very substantial advances in numeric values are needed to produce a significant advance in bivariate associations. Delay functions (usually the SMOOTH function) and (small) equation coefficients exacerbate the effects of many curvilinear relationships. The impact of these programming structures is, then, to minimize the cumulative advance in circularly related variables stipulated to occur in economic development theory. The foregoing suggests that in order for accumulative change to actually take place, curvilinear relationships must not exist and policy-induced change must be concentraded on those variables strategic to system behavior. Revision of these variables, argues Forrester,[4] transforms the performance of other system components and may eventually lead to an accumulative advance in their behavior. Hence, Myrdal's theory of circular-cumulative advance remains valid but only within the context stated above.

The implications of system stability to planner-designed change are readily evident. With respect to transportation, it appears that substantial improvements in the areal extent and frequency of transit service do not always lead to corresponding improvements in total system behavior. Based on the results of the second simulation, which embodied modifications to increase the availability of certain services to ghetto residents, it seems that transportation is a precondition and catalyst to system change but not a determinant of such change. Although transportation modifications were introduced to each submodel, only the health component evidenced a noticeable change in behavior.

The inability of transportation to induce such change corresponds to current thinking in transportation planning. Creighton[5] sees transportation as simply a vehicle to be used in obtaining broadly-held community goals, whereas Dickey,[6] in evaluating the effect of transportation upon land use, views transportation as only one of the many determinants of the use of land. This view contrasts with the thinking of locational economics and geography, which generally see accessibility as being dominant in dictating the location and density of land use development.

In fact, transportation tends to be a rather insensitive system parameter. Entered into several model equations, it failed to significantly alter system behavior. Apparently, for basic change to come about, there must be a fundamental revision of the parameters that exercise control over the system. According to Forrester, such parameters tend to occur at system decision points, and usually there are one or more of these[7] in each basic division of the system. In industrial processes these parameters, often called strategic variables, are situated at the policy-making level of the organization where questions are decided concerning the manufacturing or distributional system, the administrative structure, and the future directions of organizational growth. These decision points are not readily apparent in urban systems; recent research seems to indicate, however, that they occur amidst the economic processes of society. In the model proposed here, they probably occur in the discrimination and employment equations of the income submodel.

Based on why advances occurred - and did not occur - in the revised model, the following tentative conclusions on system change can be specified:

(1) Change, in order to be effective, must be induced through strategic variables, namely, those variables that contribute to and control system performance. In terms of the model developed here, these would occur within the income submodel because of the strong relationships between income and both health and education.

(2) If the strategic variables cannot be identified with complete certainty, change must be introduced through a broad range of (what the planner considers to be) important parameters. The disadvantage of this approach is, of course, that of the many programs developed to induce change, most will be ineffective.

(3) Change must be basic and operative over long periods of time. Without sustained change, reversion to the original low-equilibruim state is typical, according to Myrdal.[8]

The failure of many otherwise feasible urban programs, such as the neighborhood health clinic program, can be attributed to the absence of an adequate and continued funding base.

Only when these conditions are fulfilled will the size and speed of variable response be sufficiently great to push the system upward, and only then will sustained feedback loops be activated. Lacking any or all of these requisites to system revision, the basic structure and processes of the ghetto will remain unchanged and near a low-level equilibrium, as was the case in the study area between 1960 and 1970. Yet experience has shown that it is difficult to completely satisfy these preconditions.

Model Evaluation and Future Research

Although this model was developed in as accurate a way as possible, there nonetheless are certain weaknesses in the approach. Some of these will now be discussed.

The first deficiency concerns the inadequacies of the simulation approach itself. Computer models are generally formulated about the interrelationships of a strategic set of variables. These interrelationships are difficult to identify. Typically the analyst searches the literature, performs statistical analyses, and attempts by whatever means possible to identify the essential components of the system he is investigating. Unfortunately, he usually confines his search to relationships that are quantitative in nature. As a result, important social conditions are not identified or are subsumed under the more quantifiable components. This perspective embodies obvious flaws. The analyst may fail to locate precisely the variables critical to system behavior. More important, he may fail to include important social relationships as a part of the set of critical variable interrelationships. To the extent that these approaches are followed, the simulation model will be of dubious merit. Yet it should be evident that great effort has been taken in this analysis to identify the variables critical to education, health, and income relationships and to include significant social components in model interrelationships.

That the simulation covered a limited time period may be a disadvantage. Although the horizon year could have been easily extended by changing the specification card in the computer program, the relationships in the model were calibrated solely for the decade 1960-1970. The possibility exists that as the horizon year is extended, projections made by certain equations may be incorrect. It may be necessary to include a number of additional feedback loops to more accurately balance the positive growth processes embodied in many equations.

Practical and conceptual difficulties may exist with the index variables - the dropout rate, the morbidity rate, and income. It will be recalled (pages 25-26) that the accuracy of the simulation estimates is very much dependent on the utility of the index variables in representing system performance. It may be that improper index variables have been selected and that more appropriate measures of system performance could have been used. Still, great care was taken in selecting these variables, and, without exception, these measures are used by authorities in the fields of education, health, and economics.

It is questionable if the proper spatial boundaries were chosen for the study area. Although an attempt was made to define the areas of the ghetto community through research of Census and local planning agency data and through conversations with planning officials knowledgeable of the area, there still exists the possibility that important outliers of the community were not included in this analysis. This may be true expecially of the zones to the north and west of the study area where there has been a dispersal of ghetto residents in past years. These groups may still think of themselves as being part of the ghetto community and may still be closely tied to it in terms of social and economic relationships. Failure to include these areas in the analysis may, therefore, mean that the equations and feedback relationships developed in Chapter Three are not precisely matched to the actual conditions of the total ghetto community -- with attendant consequences to the simulation estimates in Chapters Four and Five.

Related to the previous criticism is the failure of this model to include the possible effects of exogeneous variables. Events are frequently controlled not by local conditions but by external influences. Economic and political decisions made at the regional and national level may well have a significant effect on local actions. A decision by a New York investor to build a manufacturing plant near the Model City area is an example of an exogeneous or external influence. Unfortunately there is no current way to predict the occurrence of these influences, much less forecast the exact repercussions of their effect. Accordingly, to the extent that the exogeneous variables influence the behavior of the study area, the simulation model lacks precision.

Finally, it may be that the simulation model is not fully geared to the dynamics of the Model City area. The equations in the model were based on a series of cuts of time series data, and while an attempt was made to calibrate the model with known change, it may be that this attempt was not wholly successful. A more dynamic modeling approach may be required to capture the full characterisitcs of system performance. Problems of time and availability, however, would probably forestall such an analysis.

Future research can profitably concentrate on the difficulties described above, should the model be found deficient in these respects. But besides these areas, other avenues of potential research include sensitivity analysis, the enlargement of the model to reflect a wider range of system relationships, and the development of a holistic model to include as subroutine the estimates generated by this model. Sensitivity analysis could be used to determine the responsiveness of the model to varying levels of uncertainty and to identify the strategic variables in the model. It may also prove useful to include more independent variables so that the complexities of reality may be more fully explained and treated. Since the programming language is very simple to use (it actually identifies mistakes in equation format and specifies appropriate corrections) and since the cost of each simulation run is very low ($2.12), the above research could be accomplished fairly easily.

Finally, it would prove estremely valuable to simulate the urban ghetto as a wholly interdependent system. This implies the inclusion of many more interrelationships to replicate fully the conditions of the ghetto over time. Our knowledge of interdependent ghetto social, economic, and behavioral processes is currently scant. Inclusion of the model developed here in a comprehensive simulation program would forestall the development of equations in the fields of health, education, and income. Effort then could be devoted to other research areas.

It is hoped that this research will encourage others to investigate the linked processes of the urban ghetto. As a field that attempts to develop and implement workable programs for social groups, it is essential that planning understand the workings of that area. It is suggested that the simulation technique provides a particularly effective way of understanding such processes. It can be especially effective in relating the social and economic dynamics of the ghetto to the conditions of the larger metropolitan area. The model developed here may provide a point of departure for that research.

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4. Forrester, Urban Dynamics, pp. 227-249.

5. Roger L. Creighton, Urban Transportation Planning (Urbana: University of Illinois, 1970), pp. 193-212.

6. Dickey, "Minimizing Economic Segregation Through....," loc. cit.

7. Forrester, Principles of Systems, p. 5-10.

8. Myrdal, Asian Drama, pp. 1843-1859.

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APPRENDIX I

Circular Cumulative Model

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CIRCULAR CUMULATIVE MODEL. INCOME EDUC HEALTH    12/05/72

 * CIRCULAR CUMULATIVE MODEL. INCOME EDUC HEALTH
 NOTE EDUCATION SUBMODEL
 L EDUC.K=EDUC.J+DT*(REA.JK-REO.JK)
 N EDUC=5160
 R REA.KL=EDUC.K*(.29)
 R REO.KL=(DROP.K*.01)*EDUC.K
 A DROP.K=TE.K+DROPSF.K+DROPSQ.K+DROPSB.K+DROPSA.K+DROPH.K+RANDOM
 A TE.K=DROPTS.K+DROPTA.K+DROPTQ.K
 NOTE STUDENT TEACHER RATIO
 A DROPTS.K=DRPTS.K*.01
 A DRPTS.K=TABLE(RDRTS,STCHG.K,22,32,1)
 T RDRTS=28.0/28.2/28.4/28.6/28.8/28.8/28.8/28.9/30.0/30.2/30.3
 A STCHG.K=ST.K/TK.K
 L ST.K=ST.J+DT*RST.JK
 N ST=5160
 R RST.KL=ST.K*(.029)
 L TK.K=TK.J+DT*RTK.JK
 N TK=178
 R RTK.KL=TK.K*(.03)
 NOTE STUD. TAIDE RATIO
 A DROPTA.K=DRPTA.K*(.015)
 A DRPTA.K=TABLE(RDRTS,STTACG.K,22,32,1)
 A STTACG.K=ST.K/TKTA.K
 A TKTA.K=TK.K+TA.K
 L TA.K=TA.J+DT*(RTA.JK)
 N TA=2
 R RTA.KL=TA.K*(.05)
 NOTE TEACHER QUALITY
 A DROPTQ.K=DRPTQ.K*(.019)
 A DRPTQ.K=TABLE(RDRTQ,TEL.K,16,18,.5)
 T RDRTQ=28.8/28.6/28.4/27.8/27.0
 L TEL.K=TEL.J+DT*(RTEL.JK)
 N TEL=16.0
 R RTEL.KL=TEL.K*(.006)
 NOTE SCHOOL FACILITIES
 A DROPSF.K=DRSF.K*(.017)
 A DRSF.K=TABLE(RDSF,SF.K,10,14,1)
 T RDSF=28.8/28.4/28.2/28.1/28.0
 L SF.K=SF.J+DT*RSF.JK
 N SF=10
 R RSF.KL=SF.K*(.01)
 NOTE STUDENT BODY QUALITY
 A DROPSQ.K=DRSQ.K*(.08)
 A DRSQ.K=TABLE(RDSQ,EI.K,1000,9000,1000)
 T RDSQ=28.6/28.8/28.8/28.6/28.0/27.2/26.5/25.7/25.0
 NOTE STUDENT OBJECTIVE BACKGROUND
 A DROPSB.K=DRSB.K*(.157)
 A DRSB.K=TABLE(RDSB,EI.K,1000,9000,1000)
 T RDSB=28.8/28.8/28.8/28.6/28.0/27.2/26.5/25.7/25.0
 A EI.K=INCOME.K*(1.0)
 NOTE STUDENT ATTITUDES
 A DROPSA.K=DRSA.K*(.171)
 A DRSA.K=TABLE(RDSA,EI.K,1000,9000,1000)
 T RDSA=28.8/28.8/28.8/28.6/28.0/27.2/26.5/25.7/25.0
 NOTE EFFECT OF HEALTH
 A DROPH.K=DRHP.K*(.05)
 A DRHP.K=TABLE(RDRHP,EH.K,0,600,100)
 T RDRHP=28.0/28.2/28.4/28.8/29.2/30.5/32.0
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CIRCULAR CUMULATIVE MODEL. INCOME EDUC HEALTH    12/05/72

 A EH.K=HEALTH.K*(1.0)
NOTE EFFECT OF OTHER VARIABLES
 C RANDOM=13.9
NOTE HEALTH SUBMODEL
 L HEALTH.K=HEALTH.J+DT*(RHS.JK-RHA.JK)
 N HEALTH=382
 R RHA.KL=HEALTH.K
 R RHS.KL=HPHYRT.K+HFACS.K+HH.K+HEDUC.K+HINC.K+RADMNH.K
NOTE PHYSICIAN RATIC
 A HPHYRT.K=HPHRTP.K*(.10)
 A HPHRTP.K=TABHL(RHPP,DOCPOP.K,.50,1.20,.10)
 T RHPP=410/400/390/380/350/310/270/210
 A DOCPOP.K=DIFDP.K-TRANSH
 A DIFDP.K=(DOCGR.K/POPGR.K)/.001
 C TRANSH=.48
 L DOCGR.K=DOCGR.J+DT*(RDOCGR.JK)
 N DOCGR=1200
 R RDOCGR.KL=DOCGR.K*(.0295)
 L POPGR.K=POPGR.J+DT*(RPOPGR.JK)
 N POPGR=1000000.00
 R RPOPGR.KL=POPGR.K*(.03)
NOTE HEALTH FACILITIES
 A HFACS.K=HFACSP.K*(.30)
 A HFACSP.K=TABLE(RHFP,FAC.K,10,15,1)
 T RHFP=382/360/340/320/300/280
 L FAC.K=FAC.J+DT*(RFAC.JK)
 N FAC=10.0
 R RFAC.KL=FAC.K*(.01)
NOTE HOUSING
 A HH.K=HOUSIN.K*(.07)
 A HOUSIN.K=TABHL(RHOP,RHO.K,50,350,50)
 T RHOP=300/320/325/380/400/500/600
 L RHO.K=RHO.J+DT*(RRHO.JK)
 N RHO=210
 R RRHO.KL=RHO.K*(-.031)
NOTE EFFECT OF EDUCATION
 A HEDUC.K=HEDUCP.K*(.123)
 A HEDUCP.K=TABLE(RHEP,HE.K,18,34,2)
 T RHEP=300/360/382/382/382/382/382/400/420
 A HE.K=DROP.K*(1.0)
NOTE INCOME
 A HINC.K=HINCP.K*(.20)
 A HINCP.K=TABLE(RINC,HI.K,2000,9000,1000)
 T RINC=382/382/360/340/325/300/280/270
 A HI.K=INCOME.K
 A RADMNH.K=HEALTH.K*(.21)
NOTE INCOME SUBMODEL
 L INCOME.K=INCOME.J+(DT)*(RIO.JK-RIA.JK)
 N INCOME=3000
 R RIA.KL=INCOME.K
 R RIO.KL=INCSOC.K+INCDSM.K+INCEMP.K
NOTE SOCIAL CAPITAL
 A INCSOC.K=INCAGE.K+INCED.K+INCHLT.K
NOTE AGE
 A INCAGE.K=INCAGP.K*(.05)
 A INCAGP.K=TABLE(RIAP,AVAGE.K,16,36,2)
 T RIAP=2800/2800/2800/3000/3000/3400/3900/4200/4800/5100/5800
 L AVAGE.K=AVAGE.J+DT*(RAVAGE.JK)
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CIRCULAR CUMULATIVE MODEL. INCOME EDUC HEALTH   12/05/72

 N AVAGE=24.0
 R RAVAGE.KL=AVAGE.K*(-.004)
 NOTE EDUCATION
 A INCED.K=INCEDP.K*(.33)
 A INCEDP.K=TABLE(RAVINE,SMOOTH(IE.K,.5),12,30,2)
 T RAVINE=16000/16000/16000/10000/8000/4200/3000/3000/3000/3000
 A IE.K=DROP.K*(1.0)
 NOTE HEALTH
 A INCHLT.K=INCHTP.K*(-.16)
 A INCHTP.K=3000+(3000-INCHMP.K)
 A INCHMP.K=TABLE(RIHP,HHLT.K,100,600,100)
 T RIHP=10000/8000/4000/3000/3000/3000
 A HHLT.K=HEALTH.K*(1.0)
 NOTE DISCRIMINATION
 A INCDSM.K=INCDRP.K*(.27)
 A INCDRP.K=TABLE(RIDP,DISM.K,0,10,2)
 T RIDP=6000/5400/4000/3000/3000/3000
 L DISM.K=DISM.J+DT*(RDISM.JK)
 N DISM=6.0
 R RDISM.KL=DISM.K*(-.03)
 NOTE EMPLOYMENT
 A INCEMP.K=INCEP.K*(.51)
 A INCEP.K=TABHL(RIED,EMPOP.K,486,6486,1000)
 T RIED=3000/3000/3000/3000/3800/4000/5000
 L EMPOP.K=EMPOP.J+DT*(REMPOP.JK)
 N EMPOP=3486
 R REMPOP.KL=EMPOP.K*(.025)
 NOTE DIRECTION CARDS
 PRINT EDUC,REA,REC,DROP,DROPTS,STCHG,ST,TK,DROPTA,STTACG,TA,DROPTQ,TE(
 PRINT DROPSF,SF,DROPSQ,DROPSB,EI,DROPSA,DROPH,EH
 PRINT HEALTH,RHA,RHS,HPHYRT,DOCPOP,DOCGF,POPGR,HFACS,FAC,HH,RHO,HEDUC,
 PRINT HINC,HI
 PRINT INCOME,RIA,RIC,INCSOC,INCAGE,AVAGE,INCED,IE,INCHLT,HHLT,INCDSM
 PRINT DISM,INCEMP,EMPOP,REMPOP
 PLOT  DROP=E/DROPTS=T/DROPTA=A/DROPTQ=Q/DROPSF=F/DROPSQ=C/DROPSB=B
 PLOT  DROPSA=P/DROPH=H
 PLOT  HEALTH=H/HPHYRT=P/HFACS=F/HH=S/HEDUC=E/HINC=I
 PLOT  INCOME=I/INCSOC=S/INCAGE=A/INCED=E/INCHLT=H/INCDSM=D/INCEMP=J
 PLOT  DROP=E/HEALTH=H/INCOME=I
 SPEC  DT=1.0/LENGTH=10.0/PRTPER=1.0/PLTPER=1.0
 RUN ' BASIC MODEL
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APPENDIX II

DEFINITION OF TERMS

Education Submodel

DROPTS.K = DRPTS.K * (0.01) 1-7,A

DROPTS DROPOUT RATE FROM TEACHER-STUDENT RATIO

DROPTS DROPOUT RATE FROM TEACHER-STUDENT RATIO, PROJECTED

DROPTA.K = DRPTA.K * (.015) 1-17,A

DROPTA DROPOUT RATE FROM TEACHER AIDE-STUDENT RATIO

DRPTA DROPOUT RATE FROM TEACHER AIDE-STUDENT RATIO, PROJECTED

DROPTQ.K = DRPTQ.K * (.019) 1-24,A

DROPTQ DROPOUT RATE FROM TEACHER QUALITY

DRPTQ DROPOUT RATE FROM TEACHER QUALITY, PROJECTED

DROPSF.K = DRSF.K * (.017) 1-30,A

DROPSF DROPOUT RATE FROM NUMBER OF SCHOOL FACILITIES

DRSF DROPOUT RATE FROM NUMBER OF SCHOOL FACILITIES, PROJECTED

DROPSQ.K = DRSQ.K * (.080) 1-36,A

DROPSQ DROPOUT RATE FROM STUDENT BODY QUALITY

DRSQ DROPOUT RATE FROM STUDENT BODY QUALITY, PROJECTED

DROPSB.K = DRSB.K * (.157) 1-39,A

DROPSB DROPOUT RATE FROM STUDENT BACKGROUND

DRSB DROPOUT RATE FROM STUDENT BACKGROUND, PROJECTED

DROPSA.K = DRSA.K * (.171) 1-43,A

DROPSA	DROPOUT RATE FROM STUDENT ATTITUDES
DRSA	DROPOUT RATE FROM STUDENT ATTITUDES, PROJECTED

DROPH. K = DRHP.K * (.05) 1-46,A

DROPH	DROPOUT RATE FROM HEALTH
DRHP	DROPOUT RATE FROM HEALTH, PROJECTED

Health Submodel

HPHYRT.K = HPHRTP.K * (.10) 1-56,A

HPHYRT	HEALTH FROM PHYSICIAN-PATIENT RATIO
HPHRTP	HEALTH FROM PHYSICIAN-PATIENT RATIO, PROJECTED

HFACS.K = HFACSP.K * (.30) 1-68,A

HFACS	HEALTH FROM NUMBER OF FACILITIES
HFACSP	HEALTH FROM NUMBER OF FACILITIES, PROJECTED

HH.K = HOUSIN.K * (.07) 1-75,A

HH	HEALTH FROM HOUSING
HOUSIN	HEALTH FROM HOUSING, PROJECTED

HEDUC.K = HEDUCP.K * (.123) 1-81,A

HEDUC	HEALTH FROM EDUCATION
HEDUCP	HEALTH FROM EDUCATION, PROJECTED

HINC.K = HINCP.K * (.20) 1-84,A

HINC HEALTH FROM INCOME

HINCP HEALTH FROM INCOME, PROJECTED

Income Submodel

INAGE.K = INACP.K * (.05) 1-94,A

INAGE INCOME FROM AGE

INCACP INCOME FROM AGE, PROJECTED

INCED.K = INCEDP.K * (.30) 1-100,A

INCED INCOME FROM EDUCATION

INCEDP INCOME FROM EDUCATION, PROJECTED

INCHLT.K = INCHTP.K * (-.16) 1-104,A

INCHLT INCOME FROM HEALTH

HCHTP INCOME FROM HEALTH, PROJECTED

INCDSM.K = INCDSP.K * (.27) 1-108,A

INCDSM INCOME FROM EFFECTS OF DISCRIMINATION

INCDSP INCOME FROM EFFECTS OF DISCRIMINATION, PROJECTED

INCEMP.K = INCEP.K * (.51) 1-114,A

INCEMP INCOME FROM EMPLOYMENT

INCEP INCOME FROM EMPLOYMENT, PROJECTED

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SIMULATION OF

THE RELATIONSHIP BETWEEN CERTAIN SOCIAL FACTORS AND TRANSPORTATION IN A LOW INCOME AREA

by

Bruce Gordon Phelps

Abstract

A computer simulation model of the relationship between education, health, and income was developed for a low-income area of Miami, Florida. A basic assumption was that a causal, circular relationship exists among these factors and that change in one will give rise to an accumulative advance in the others.

The estimates obtained from the model were for the ten year period 1960-1970. They confirmed the general absence of change in the study area. The education, health, and income components remained at or near original levels.

Using these estimates as a datum, modifications were then introduced into certain model variables to simulate the effect of an improved transit system. With the exception of health, which did seem to be noticeably affected by transit service, the general pattern of the study area remained unchanged.

The conclusions of this research were that:

1. Low-equilibrium systems, such as the urban ghetto, have substantial inertia in their social processes. This inertia minimizes the effects of social and economic change.

2. Change, to be effective, must concentrate on strategic system variables and must be of large magnitude and occur over a long period.

3. The circular connectivity of processes in ghetto systems is not strong. As a result, a cumulative upward charge in the ghetto is difficult to achieve.

4. Transportation does not appear to be an important catalyst to system change.