# TOWARD A FORMALIZATION OF DEMOGRAPHIC TRANSITION THEORY

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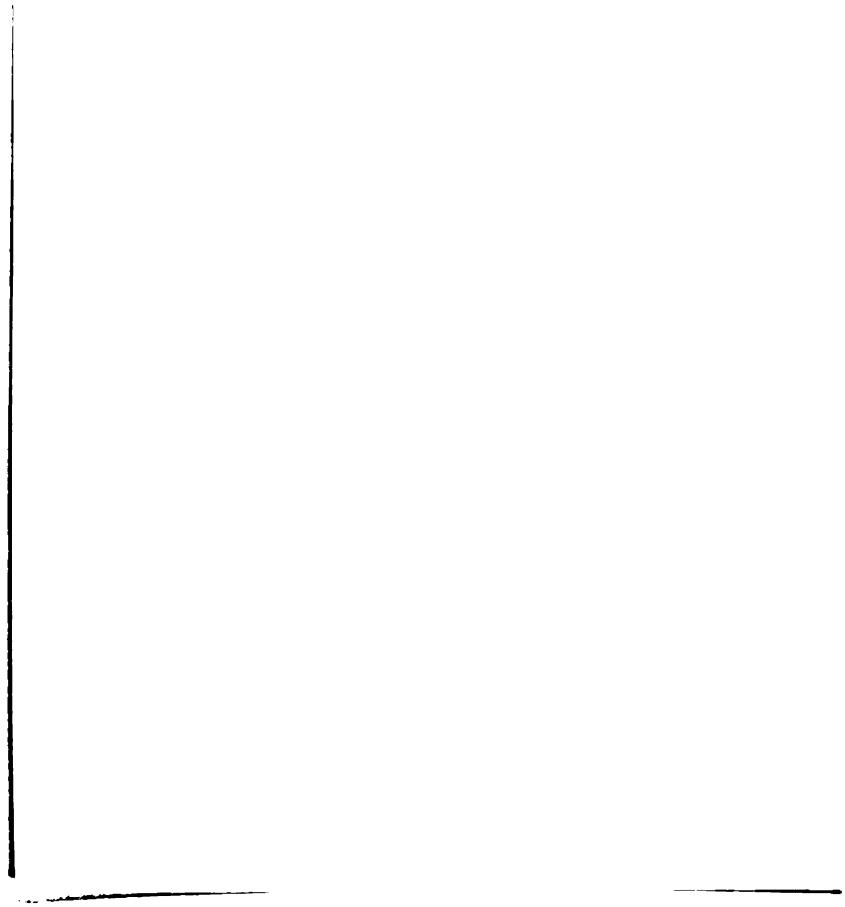

ABSTRACT

TOWARD A FORMALIZATION

OF DEMOGRAPHIC TRANSITION THEORY

by

S. Charles Lazer

An explication and analysis of demographic transition theory yield sixteen propositions which are adduced to account for the phenomena described by the theory. These propositions form the basis of a planned computer simulation of demographic transition. Setting the parameters of this model according to historical data make it capable of partial verification as a theory, while changing parameters and processes lend the model the ability to explore the theory more fully.

# TOWARD A FORMALIZATION OF DEMOGRAPHIC TRANSITION THEORY

by

S. Charles Lazer

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> It is difficult to avoid the conclusion that the major advances in the science of population have come from improvements in the sources of information and in the techniques of analysis rather than from the broad interpretations. [1]

The lack of valid formal theory in demography has been repeatedly indicated and the need for it is sharply felt. [2] This lack is especially striking, if only for the fact that "over-arching theories.... (have) dominated so much of the nineteenth century work" [3] in the discipline, without a commensurate advance in the development of theory. At best, what are generally considered by demographers to be theory are empirical generalizations, i.e., "a set of uniform conjunctions of traits repeatedly observed to exist, without any understanding of why the conjunction occurs; without a theory which states its rationale." [4] At worst, the preoccupation with such "over-arching theories" which

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1. Kingsley Davis, "The Sociology of Demographic Behavior," in Robert K. Merton, Leonard Broom, Leonard S. Cottrell, Jr. (eds.), Sociology Today (New York: Basic Books, 1959), p. 313.

2. See for example, Robert Gutman, "In Defense of Population Theory," American Sociological Review, v. 25, 1969, pp. 325-333 and Rupert Vance, "Is Theory for Demographers," Social Forces, v. 31, 1952, pp. 9-13.

3. Frank Notestein, in B. F. Haley (ed.), Survey of Contemporary Economics, v. II. (Homewood: Irwin, 1952), p. 129, cited in Warren C. Robinson, "The Development of Modern Population Theory," American Journal of Economics and Sociology, v. 23, 1964, p. 376.

4. John Dewey, Logic: The Theory of Inquiry (New York: Holt, 1938), p. 193.

are often no more than simply "a long stretch of verbal analysis"[5] has probably retarded the development of the discipline.[6]

One of the dominant theories, if we understand theory in demography to be used in its broadest sense as a set of general statements or principles which "organize existing knowledge, lead to the acquisition of new knowledge, and help in the solution of population problems,"[7] today is that of the demographic transition, an attempt to explain population growth and which is derived historically from the vital experiences of Western Europe.

> It would scarcely be an exaggeration to call it "The" modern population theory.... (however).... It is at the same time a very general theory lacking in rigourous formulations, or neat precise answers to complex questions of population change.[8]

Since its initial formulation by Thompson in 1929[9] some attempts have been made to state the theory in a more formal manner.[10]

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5. Kingsley Davis, loc. cit.

6. Frank Notestein, loc. cit.

7. Robert Gutman, op. cit., p. 333.

8. Warren C. Robinson, op. cit. p. 389.

9. Warren S. Thompson, "Population," American Journal of Sociology, v. 34, 1929, pp. 959-975.

10. See for example, Donald O. Cowgill, "Transition Theory as General Population Theory", Social Forces, v. 41, 1962, pp. 270 - 274 and Paul K. Hatt, N. L. Farr, E. Weinstein, "Types of Population Balance," American Sociological Review, v. 20, 1955, pp. 14-20.

However, "the reasoning underlying the statement remains implicit at the present time."[11] This paper, then, will attempt to present the transition theory in systematic fashion, hopefully stating the assumptions and propositions explicitly in terms of the proposed simulation in order to move from the level of description to that of explanation. Such a move can only facilitate the determination of a causal nexus and its underlying rationale.

To state that there is some confusion in Sociology as to the meaning of the term and the nature of "Theory" is an understatement, and the realm of this question is beyond the scope of this paper. However, to state categorically, as some have done, that

> Grand programs for constructing theories have not enlarged our knowledge and understanding of society nor have they proved to be realiable guides for social research [12]

and further that such theories are by their definition devoid of empirical referents can only be at best misleading.

Theory, or more specifically, logical explanation can be defined as consisting of two parts, the explanandum and the explanans, such that

> By the explanandum, we understand the sentence describing the phenomenon to be explained (not that phenomenon itself); by the explanans, the class of those sentences which are

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11. Robert Gutman, op. cit., p. 332.

12. Ibid., p. 333.

> adduced to account for the phenomenon.... the explanans falls into two sub-classes; one of these contains certain sentences $C_1, C_2, \ldots C_k$ which state specific antecedent conditions; the other is a set of sentences $L_1, L_2, \ldots L_r$ which represent general laws.[13]

Further, the explanation must meet certain criteria of adequacy:

1) The explanandum must be a logical consequence of the explanans, in other words, the explanandum must be logically deducible from the information contained in the explanans...

2) The explanans must contain general laws, and these must actually be required for the derivation of the explanandum...

3) The explanans must have empirical content, i.e. it must be capable, at least in principle, of test by experiment or observation...

4) The sentences constituting the explanans must be true.[14]

This, then, is "Theory" but what of the "Demographic Transition"? The transition is an attempt to explain the rapid population growth experienced by the "Western" civilizations in the recent past and the ensuing S-curve depicting population size, and thence to predict the growth which could be expected in the developing nations as they approach and then pass through successive stages of modernization. In the first statement of the transition, selected countries of the world were classified according to their natural rates and

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13. Carl G. Hempel and Paul Oppenheim, "The Logic of Explanation" in Herbert Feigl and May Brodbeck (eds.), Readings in the Philosophy of Science (New York: Appleton-Century-Crofts, 1953,) p. 321.

14. Ibid, pp. 321-322.

consequently their growth rates, with the processes underlying the taxonomy left implicit. The classifications arrived at were:

> Group A countries: Very rapid declining birth-rate and death-rate with the former declining more rapidly than the latter so that the rate of natural increase is also declining.
>
> Group B: ....decline in both birth-rates and death-rates is underway in certain classes, but....the death-rate is declining rapidly or even more rapidly than the birth-rate with the result that the rate of natural increase will probably for sometime remain as great as now, or even become larger in the near future.
>
> Group C: Both birth-rates and death-rates are less controlled than in either A or B. But in some of these countries....there is some indication that death-rates are coming under control faster than birth-rates. In such of these lands as are developing modern industry and sanitation, there is very likely to be a very rapid increase in numbers during the next few decades. In many of these lands, however, both birth-rates and death-rates are quite uncontrolled and we may expect either a rapid increase or almost a stationary population dependent upon the harshness of the "positive" checks to population growth....[15]

Represented graphically, the three groups would appear as below:

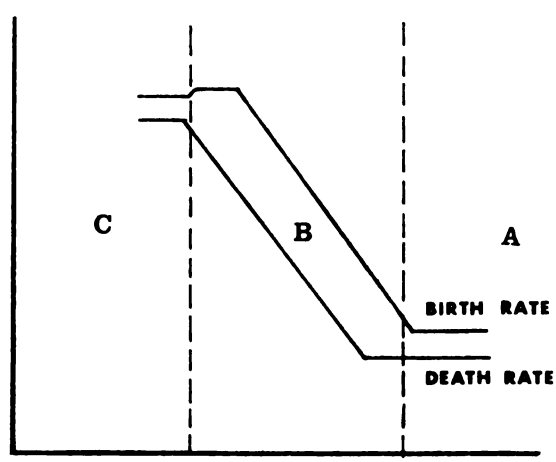


**FIGURE 1: The Demographic Transition**

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15. Warren S. Thompson, op. cit., pp. 961-962.

The countries classified as belonging to Group A were the most modern, those of Group B were undergoing modernization, and those in Group C were described as primitive. The representation is one of a shifting control over the natural functions--from a biological determinism of mortality and fertility to a more rational one.[16] Rapid growth occurs because death rates tend to fall more quickly than do birth rates. The first statement of what has since become known as the demographic transition is simply: Declining rates of mortality and fertility are associated with modernization, and further that mortality will decline earlier than fertility.

Although there are at least four simple cycles of the vital rates that will yield the S-shaped demi-cycle of population growth experienced by the nations which have undergone modernization[17] (see Figure 2 below) only Cycle II is associated with transition theory. Cycle I may be found in primitive societies where fertility is relatively fixed and growth is dependent solely on fluctuations in mortality. Cycle III has not manifested itself as yet, but may appear in future societies wherein mortality control can be extended no further so that growth may only be determined by fluctuations in fertility. Cycle IV has not appeared to this date, and there is little reason to assume that it will appear in the future.

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16. See, for a brief discussion, Leighton van Nort, "Biology, Rationality, and Fertility, a Footnote to Population Theory," Eugenics Quarterly, v. 3, 1956, pp. 157-160.

17. Donald O. Cowgill, "The Theory of Population Growth Cycles," American Journal of Sociology, v. 55, 1949, pp. 163-170.

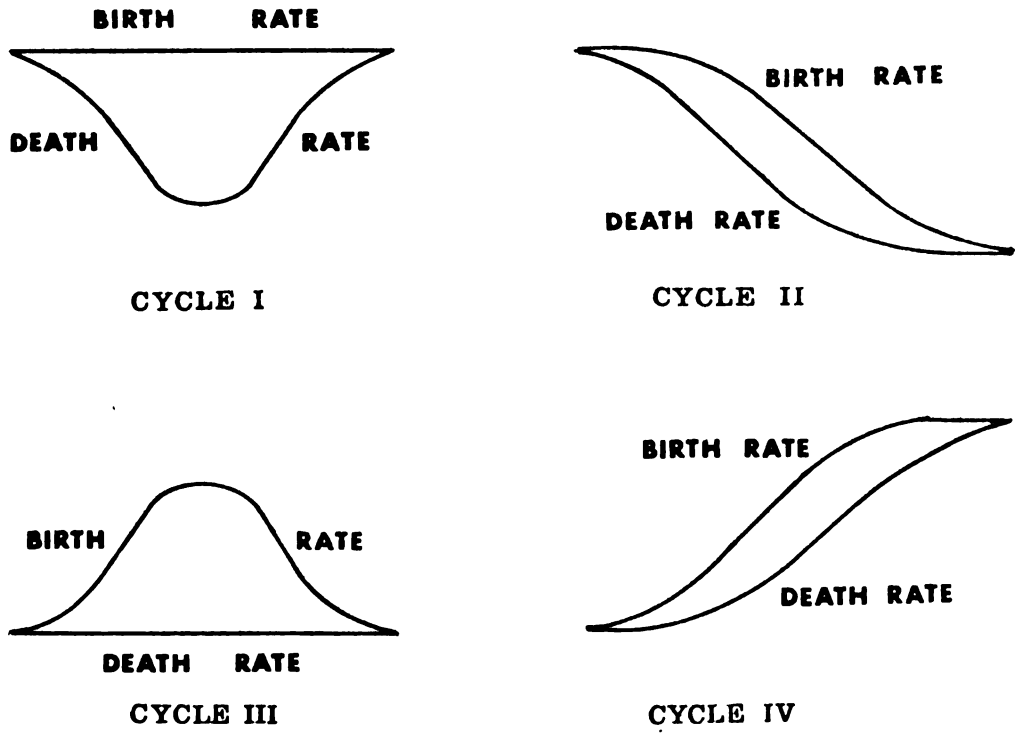


**FIGURE 2: Plausible Vital Rate Cycles**

Consequently, further development of the theory--mostly notably by A. M. Carr-Saunders,[18] Kingsley Davis,[19] and especially Frank Notestein[20]--was concerned primarily with the establishment and refinement of its implicit causal mechanisms and not with the

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18. A. M. Carr-Saunders, World Population (Oxford: Clarendon Press, 1936).

19. Kingsley Davis, "The World Demographic Transition," The Annals, v.237, 1945, pp. 1-11.

20. Most notably, Frank Notestein, "Population - The Long View" in Theordore W. Schultz (ed.), Food for the World (Chicago: University of Chicago Press, 1945), pp. 36-57.

nature and shape of the growth pattern as postulated.[21] A succinct modern statement of the sequence of events underlying the demographic transition may be given as follows:

> The agrarian low-income economy is characterized by high birth and death rates--the birth rates relatively stable and the death rates fluctuating in response to varying fortunes. Then as the economy changes its form to a more interdependent and specialized market-dominated economy, the average death rate declines. It continues to decline under the impact of better organization and improving medical knowledge and care. Somewhat later the birth rate begins to fall. The two rates pursue a more or less parallel downward course with the decline in the birth rate lagging behind. Finally, as further reductions in the death rate become harder to obtain, the birth rate again approaches equality with the death rate and a more gradual rate of growth is reestablished, with, however, low risks of mortality and small families as the typical pattern. Mortality rates are now relatively stable from year to year and birth rates--now responsive to voluntary decisions rather than to deeply imbedded customs--may fluctuate from year to year.[22]

We now have a verbal statement of some of the relationships implicit in earlier formulations. The variables incorporated into this model as influencing mortality and fertility are market economy, organization, and medical care.

However, because of the difficulty of extracting precise

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21. The scope of this paper precludes a detailed dicussion of the evolution of the Demographic Transition Theory. However, for an extensive discussion of the matter and an almost exhaustive English bibliography on the subject, see Grafton D. Trout, Jr., "The Development and Current Status of the Demographic Transition Theory, A Bibliographic Survey" (1963, unpublished).

22. Ansley J. Coale and Edgar M. Hoover, Population Growth and Economic Development in Low-Income Countries (Princeton: Princeton University Press, 1958), p. 13.

information from such verbalizations, some recent attempts have been made to state the theory in propositional form. The advantages of this form are that "it forces him (the theorist) to spell out his assumptions, to make explicit his deductions, and it will remind him of any bypassed implications."[23]

Hatt, Farr and Weinstein posit

> That mortality and fertility are so related to urbanization and industrialization that low levels of the vital rates are associated with high levels of modernization; and that high levels of vital rates are associated with low levels of modernization; and further, that medium levels of modernization will serve to depress mortality more rapidly than fertility.[24]

The propositions are formulated in this fashion in order that some of the relationships expressed in the theory may be assessed. But it is interesting to note that a causal connection in only brought out in the third part of the statement.

A second formal statement of some aspects of the transition theory is somewhat more ambitious. Shifting "from the use of the economists' conventional variables--land, labor and capital--to population, technology and culture,"[25] Cowgill sets forth twelve propositions which are in essence, generalizations induced from

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23. Hans L. Zetterberg, On Theory and Verification in Sociology. Third Enlarged Edition (Totawa, New Jersey: Bedminster Press, 1965), p. 100.

24. Paul K. Hatt et al., op. cit., p. 15.

25. Donald O. Cowgill, op. cit. (1962), p. 274. [illegible] Social Forces, Vol. [illegible], p. 274.

empirical research in population growth, and which are more concerned with various differential rates experienced by populations in transition from high equilibrium mortality and fertility to low equilibrium mortality and fertility, than with the generation of the transition itself. The propositions relevant to the transition itself are set down below:

1) In the absence of effective technology of birth control and death control, population will increase to a maximum carrying capacity of the environment, then achieve a stable equilibrium characterized by high birth rates and limited longevity.

2) Under conditions of industrialization and urbanization, given the technology of birth control and death control, there is a marked tendency for the technology of death control to be applied earlier and more extensively, resulting in rapid population growth and extensive structural changes in the population. Later, and less predictably, cultural values permitting, the technology of birth control may be employed to reduce the rate of growth and bring about a new condition of equilibrium.

3) During the process of urbanization and industrialization, the nuclear family tends to replace extended and consanguine forms.

4) With a falling birth rate, the size of the nuclear family tends to decline.

5) During the demographic transition there is a marked shift from extractive industries and agrarian occupations to industrial and commercial occupations.

6) During the demographic transition there is a marked tendency toward urbanization of the population.[26]

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26. Ibid.

The need for a formal statement of the demographic transition theory still exists. According to Cowgill, the most pressing need is for those studies which will shed the most light on "the factors inhibiting and promoting the application of birth control technology."[27] However, that the need for increased knowledge of those factors affecting mortality decline as well is no less pressing has been indicated in not so gentle a manner by some critics of the Theory.[28] In other words the question still asked is: "How does transition theory work?", both in terms of historial explanation of the European experience and of prediction in the Third World today.

In order to gain the greatest amount of understanding of the demographic transition, and to facilitate the formulation of propositions regarding it, the transition was considered to consist of two processes: mortality decline and fertility decline. This is not to imply that the two are unrelated, but simply that the greatest benefits can be obtained by treating them separately, without doing serious damage to the theory. The factors which affect one do not always affect the other and, in historical accounts of the transition wherein

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27. Ibid, p. 274.

28. See, for example, William Petersen, "The Demographic Transition in the Netherlands," American Sociological Review, v. 25, 1960, pp. 334-347, and Leighton van Nort, "Some Issues for Transition Theory," Population Index, v. 26, 1960, pp. 387-395, and Dennis Wrong, Population (New York: Random House, 1956), Ch. 2.

variables considered to affect the vital rates are endogenous rather than exogenous, do not occur simultaneously. In addition, the variables considered to influence the vital rates were considered to act as independently of each other, not because their interdependence was felt to be either non-existent or negligible, but rather because it was felt that this would introduce severe complications into the model, which could only render it almost unworkable at this early stage of the analysis. In Zetterberg's terms, "propositions with two variates are acceptable as intermediary steps in theory construction even if they do not tell the whole story. Once formulated they lend themselves to amendments."[29] These amendments are logical and necessary refinements which the model must undergo, but the independence restriction is necessary at this point.

The dependent variables of the propositions--statements of relationships between at least two variables[30]--formulated below were considered to be

a) the mortality rate

and

b) the fertility rate.

The independent variables were derived from the works of several students of the problem. The variables listed in Table 1 are superordinate categories of the generally more specific variables

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29. Hans L. Zetterberg, op. cit., p. 65.

30. Ibid, p. 64.

indicated as affecting the mortality rate. The names used to represent the variables in the model are given in parentheses.

TABLE 1

VARIABLES INFLUENCING THE MORTALITY RATE (MORTY)

| Author | Political stability (ORDER) | Improved resource extraction (AGTEX) | Improved food supply and diet (DIET) | Improved transportation and communication network (TRANCOM) | Improved public sanitation (SANTEX) | Increased medical technology and improved medical care (MEDTEX) | Modernization (MODERN) |
|---|---|---|---|---|---|---|---|
| Thompson | | X | | | X | | X |
| Carr-Saunders | X | | X | | X | X | X |
| Notestein | X | X | X | | X | X | X |
| Davis | X | X | X | X | X | X | X |
| Blacker | X | X | X | X | X | X | X |
| Wrong | X | X | X | X | X | X | |
| Cowgill | | X | | | | X | X |
| Petersen | | | X | | X | X | |
| Coale and Hoover | X | X | X | X | X | X | X |

Propositions concerning the declining mortality rates described by transition theory were then formulated using the variables shown in Table 1 and which were felt to accurately represent the relationships implied or expressed by the theory. The variable "modernization" was not used inasmuch as it was felt that the other variables were all manifestations of it. "Modernization" is differentiable from the other variables if it is conceived of in terms of an attitudinal configuration, rather than technological progress. However, because mortality reduction is almost universally viewed positively, it is unnecessary to take it into consideration in the model being developed here.

If

a) A primitive state of no significant mortality control will serve to maintain a high mortality rate

is initially posited the following propositions regarding the mortality rate in the demographic transition may then be generated:

b) Increased political stability will contribute to a declining mortality rate.

c) Improved resource extraction will contribute to an improved food supply and diet.

d) An improved transportation and communication network will initially contribute to an improved food supply and diet.

e) An improved food supply and diet will contribute to a

declining mortality rate.

f) Improved public sanitation techniques will contribute to a declining mortality rate.

g) Increased medical technology and improved medical care will contribute to a declining mortality rate.

h) Continued declining mortality will eventually yield (when the limit of mortality control is achieved) a low stable mortality rate.

By the identical process the variables considered to influence the fertility rate as shown in Table 2 were induced.

TABLE 2

VARIABLES INFLUENCING THE FERTILITY RATE (FERTY)

| Author | Contraceptive methods, their accessibility and availability (OZ) | Traditional value system predisposed to high fertility (CUSTOM) | Urbanization (URBAN) | Industrialization (INDUST) | Modernization (MOD) | Value system predisposed to low fertility (NUVALU) |
|---|---|---|---|---|---|---|
| Thompson | X | | | | | |
| Carr-Saunders | X | | | | X | X |
| Notestein | | X | X | X | X | X |
| Davis | | X | X | | X | X |
| Blacker | | | X | X | X | |
| Kirk | | | | | | X |
| Hatt, Farr, Weinstein | | | | | X | |
| Van Nort | | | | | | X |
| Coale and Hoover | X | X | X | | X | X |
| Petersen | | X | | | | X |
| Robinson | X | | | | | X |

Here again, the variable "Modernization" was omitted from the simulation, as it was felt that the more specific variables "Urbanization" and "Industrialization" were adequate indicators of the technological aspects of "Modernization", and that the attitudinal configuration implied was represented by the variable "New value system." The existence of a value system outside of a social structure is inconceivable, and consequently it was felt that the incorporation of "Modernization" into the simulation would be redundant.

Further, if we assume that one of the functional prerequisites of a viable society is replacement of its population, we may stipulate:

i) A primitive state of nature with no significant mortality control will favor a traditional value system predisposed to high stable fertility

and formulate the following propositions regarding the fertility decline:

j) A traditional value system predisposed to high fertility will contribute to maintaining a high stable fertility rate.

k) Urbanization will contribute to the establishment of a value system which is predisposed to a low stable fertility rate.

l) Industrialization will contribute to the establishment of a value system which is predisposed to a low stable fertility rate.

m) Industrialization will contribute to increased urbanization.

n) A value system which is predisposed to low stable fertility will contribute to a declining fertility rate.

o) The availability and accessibility of contraceptive techniques will contribute to a declining fertility rate.

p) Continued declining fertility will eventually yield (when the limit of fertility control is achieved) a low stable fertility rate.

Thus, we may generate sixteen propositions, eight pertaining to the mortality decline and eight pertaining to the fertility decline experienced in the demographic transition. Further, if we assume that improved transportation and communication networks are among the earliest indicators of a more general modernization we may stipulate:

q) Improved transportation and communication networks will precede a more general modernization, i.e. urbanization and industrialization,

and thereby, with (i), provide points of connection between the two processes of mortality decline and fertility decline.

Examining the sixteen propositions stated above, and substituting the labels of the variables for the variables themselves, with the addition of HIMORT: a high mortality rate and DEMORT: a declining mortality rate as well as HIFERT: a high fertility rate, and DEFERT: a declining fertility rate and using the connectives $\underline{\vee}$, exclusive disjunction, and $\rightarrow$, conditional, we may then state the

following fifteen propositions in symbolic form:

| | | | | |
|---|---|---|---|---|
| 1) | NATURE | → | HIMORT | (a) |
| 2) | ORDER | → | DEMORT | (b) |
| 3) | AGTEX | → | DIET | (c) |
| 4) | TRANCOM | → | DIET | (d) |
| 5) | DIET | → | DEMORT | (e) |
| 6) | SANTEX | → | DEMORT | (f) |
| 7) | MEDTEX | → | DEMORT | (g) |
| 8) | NATURE | → | CUSTOM | (i) |
| 9) | CUSTOM | → | HIFERT | (j) |
| 10) | URBAN | → | NUVALU | (k) |
| 11) | INDUST | → | NUVALU | (l) |
| 12) | INDUST | → | URBAN | (m) |
| 13) | NUVALU | → | DEFERT | (n) |
| 14) | OZ | → | DEFERT | (o) |
| 15) | TRANCOM | → | URBAN | (p) |

Thus a system of propositions has been created from which the demographic transition phenomenon may be deduced. The propositions all contain empirical content, they can all be verified, and if it is assumed that the propositions may achieve the status of general laws, then the system is capable of verification as a logical explanation or theory according to the criteria of Hempel and Oppenheim cited above.

With demographic transition theory stated in propositional

form, the construction of a rudimentary stochastic simulation model is greatly facilitated. One need only make the further stipulation that the variables act sequentially as well as independently. That this aspect of the transition is not unwarranted in any event is implied by descriptions of populations which have naturally undergone the transition from high mortality and fertility to low mortality and fertility.[31]

Flow charts of the simulation models of the mortality and fertility declines are shown in Figures 3 and 4 below and it is interesting to note that proposition 15)

$$\text{TRANCOM} \longrightarrow \text{URBAN}$$

permits the connection of the two simulations, and at the same time introduces the element of a time lag between the initial decrease of mortality and that of fertility.

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31. See for example, Kingsley Davis, op. cit. (1945), Frank Notestein, op. cit. (1945), and Dennis Wrong, op. cit.

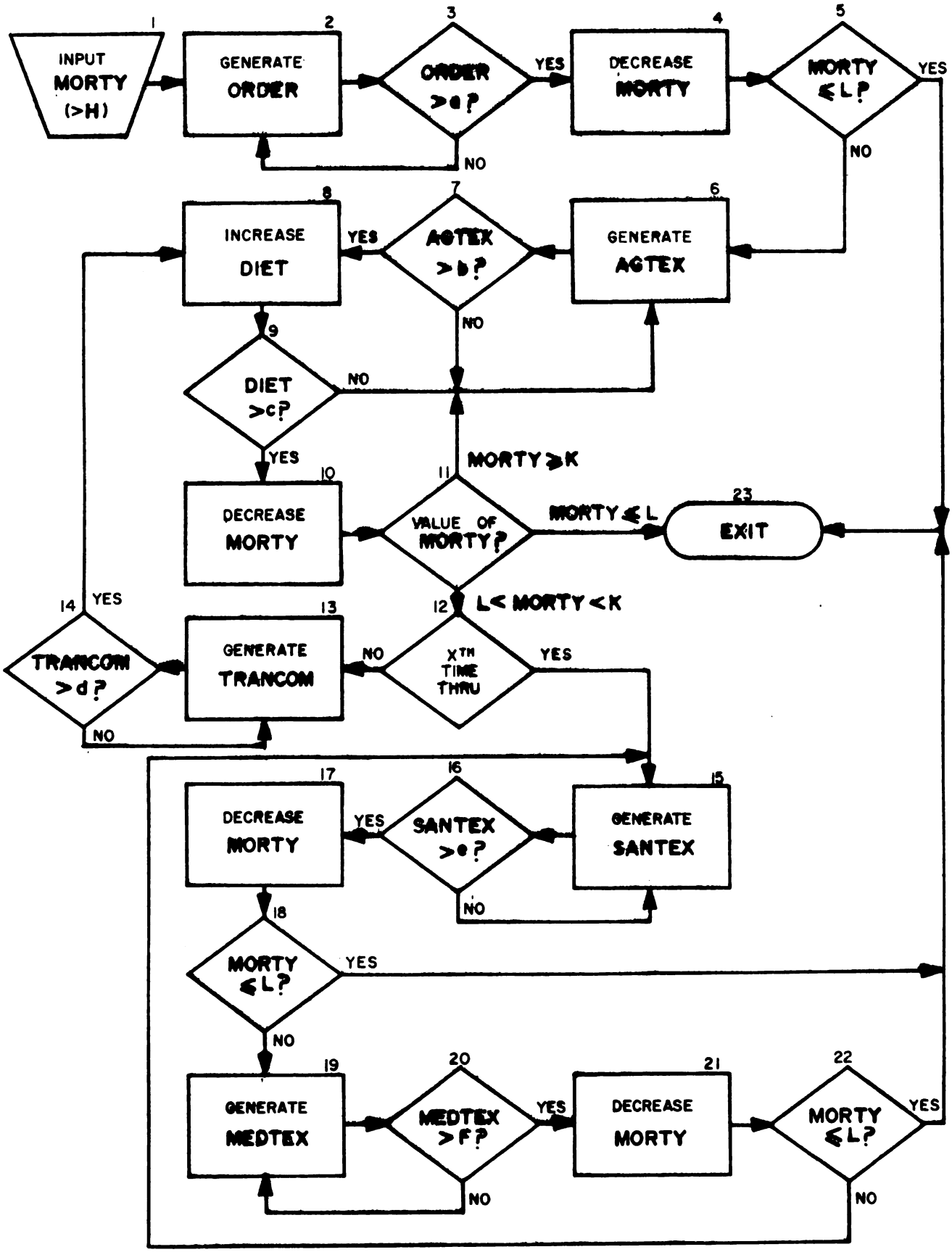


FIGURE 3: MORTALITY DECLINE

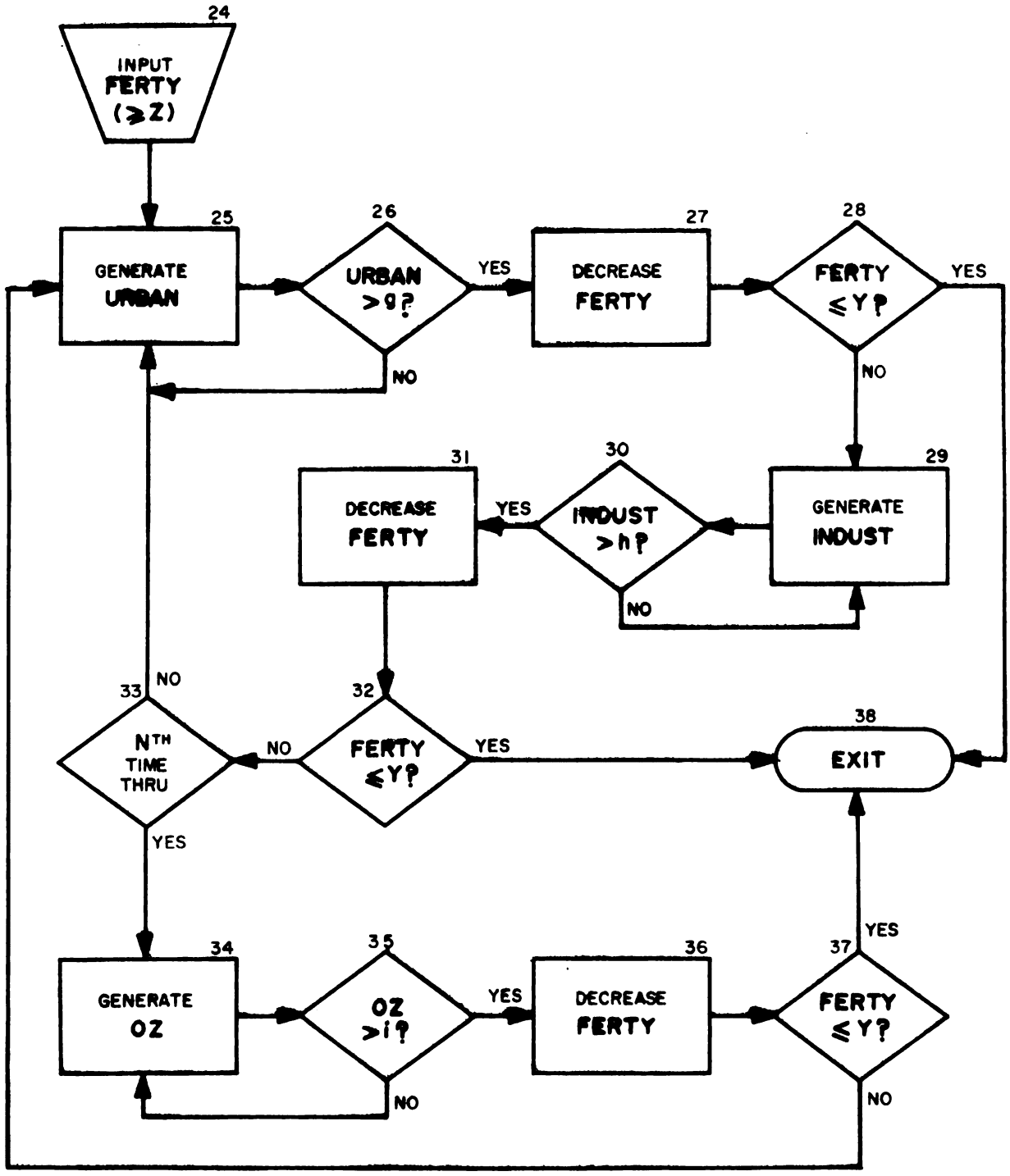


FIGURE 3: FERTILITY DECLINE

The mortality parameters H, K, and L are those which primarily determine the operation of the mortality simulation.

H is that level of the death rate sufficiently high that the population with MORTY $\geq$ H can be assumed to have not yet entered the transition phase. In fact, this value has generally ranged from 40 to 70. In the simulation, a specific mortality rate could be input, if a prediction of a given population were desired, or probabilities of occurrence could be assigned the various rates and an input generated by the machine.

K is that death rate $<$ H above which the population is considered to be affected only by the earliest and simplest of variables contributing to mortality decline. It is in the stage when K$<$MORTY$<$H, that mortality decline is gradual. K has generally ranged, in actual experience, from H-6$\leq$K$\leq$H-3. The value of K can be set arbitrarily, generated by the program in the same fashion as H, within the above-mentioned limits, or even the natural limits may be varied to suit the purpose of the operator.

L is defined as that level of the death rate sufficiently low that the population with MORTY$\leq$L can be assumed to have undergone the transitional phase of mortality decline and to have achieved a low stable death rate. The mortality simulation is terminated. It is in the stage of L$<$MORTY$<$K

that mortality is assumed to undergo its most precipitious decline. L has traditionally assumed an actual value of $15 \leqslant L \leqslant 25$. The simulation could determine the value of L for any particular run in the same manner as was used to determine the values of H and K.

The fertility parameters, Y and Z are determined as the mortality parameters and they are defined:

Z that level of the birth rate sufficiently high that the population with FERTY $\geqslant$ Z can be assumed to have not entered the transitional phase of fertility decline. Historically this value has generally ranged from $40 \leqslant Z \leqslant 70$.

Y that level of the birth rate sufficiently low that the population with MORTY $\leqslant$ Y can be assumed to have undergone the transitional phase of fertility decline and to have achieved a low stable birth rate. The fertility simulation is terminated. This figure has generally ranged, in fact, from $25 \leqslant Y \leqslant 35$.

These, then, are the parameters that determine the basic operations of the simulation programs: inputs, the shift of the mortality simulation from the initial cycle of gradual decrease to the second cycle of rapid decline, and terminations.

The independent and intervening variables used in the simulation, ORDER, AGTEX, DIET, TRANCOM, SANTEX, MEDTEX, URBAN, INDUST and OZ, and their corresponding parameters (which

may perhaps be best interpreted as threshold values), a, b, . . . . i, all operate in the same fashion. Consequently, an explanation of their operation may be most easily understood by observing the operation of one of these operators, eg. ORDER.

ORDER is defined as political stability. Any process or event which contributes to such stability may be viewed as belonging to the class ORDER. It is from this class of events that the single event indicated by the flowchart process "Generate ORDER" is chosen. If the simulation were being used for purposes of prediction, either historical prediction or the prediction of future events based on specific occurrences, the variable or variables desired could be selected and inserted into the simulation. If the model were being used to simulate the vital history of population undergoing no predetermined processes the events of the class ORDER, $O_1$, $O_2$, . . . . ,$O_n$, could be assigned probabilities of occurrence, which could be historically based or which could be derived from a set of propositions about antecedent conditions peculiar to the population, such as cultural norms, technology, etc. Regardless of the derivation of the probabilities they would be of the form

$$Po_1 + Po_2 + \ldots + Po_n = 1$$

and an event of the class ORDER, $O_i$, would be generated at cell 2.

To each $O_i$ would be assigned a numerical value $Vo_i$ which may be either positive or negative and considered to represent the impact that such an event would have on the mortality rate, e. g. the

establishment of a strong central government where none existed before, $O_a$, might be assumed to have a greater impact on mortality, i.e. cause a greater reduction, than would the establishment of a (different) feudal system, $O_b$, and $Vo_a > Vo_b$. As with the probabilities of occurrence, $Vo_i$ may be derived either historically or from a set of propositions regarding the population being simulated.

$Vo_i$ is then evaluated at cell 3, the point "ORDER>a?", where a is assumed to be the minimum value of $Vo_i$ which will affect the mortality rate. Consequently, if $Vo_i \leq a$ the model loops back to "Generate ORDER" and generates $Vo_{i+1}$. This loop is repeated until $Vo_i + Vo_{i+1} + \ldots + Vo_{i+n} > a$, at which point the death rate can be decreased at "Decrease MORTY " (cell 4). The magnitude of a is obviously related to $Vo_i$ and is determined in the same fashion.

The operation "Decrease MORTY" is actually a two-stage process. Continuing with the example, ORDER, $Vo_i$ may be construed to be the impact of $O_i$ on the mortality rate. Consequently, it may be assumed that the amount of mortality decline generated in "Decrease MORTY" is proportional to $Vo_i - a$, where $Vo_i > a$. The exact nature of the proportion can be deduced from historical data, or from a set of propositions concerning the simulated population.

The repeated mention of more than one method of assigning values to the parameters of the model arises from the multiplicity of functions which the model is capable of performing. Its major functions would be partial verification of demographic transition

theory and prediction of population growth under varying conditions, as well as exploration of the theory itself. The most pressing theoretical question historically is that of the nature of the relationship between the components of the variable "Modernization" and its effect on the social structure and value system. With regard to the present, an examination of the effects on the process of changes in the order of the events as well as extensions and compressions of the time factor involved would almost certainly prove fruitful.

However, before either operation could be attempted with any degree of confidence in the relevance of the findings, the model itself must be validated. The validation technique employed would be that of finding a "best-fit simulation" in a manner similar to that followed by Pool, et. al., in Candidates, Issues and Strategies: A Computer Simulation.[32] The data on vital rates for several Western European countries having undergone the demographic transition "naturally" is available and is considered reasonably accurate as far back as the eighteenth century. Calibration would then be concerned with adjusting the processes and parameters of the model so that the output of the model most closely approximates the vital experience of the actual population it is being compared with. This "best-fit" technique would not only attempt to achieve a correspondence at the beginning and end of the transition, but also to achieve a correspondence at each stage

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32. Ithiel Pool, R. P. Abelson and Samuel Popkin, Candidates, Issues and Strategies: A Computer Simulation (Cambridge: The MIT Press, 1965).

in the process. This is necessary because similar outputs of the simulation and the actual experience do not necessarily imply that the processes by which the outcomes are determined are congruent. If the outcomes for the several stages of the vital processes and of the model are also similar the probability of the model's being an accurate representation of vital experience is greatly increased.

Once the model has been calibrated and the parameters established the use of the model for theory verification is straightforward. Renewed interest in historical demography has made itself felt in recent years[33] and has improved the quality as well as quanitity of data available on populations of two centuries ago. Furthermore, techniques of analysis of such data have also been improved. Consequently, a more accurate portrait of historical population growth can be presented. If the simulation is constructed with inputs identical to those of history, then the outcomes may be compared. Congruent outcomes will not prove the theory or any of its propositions true, but dissimilar outcomes are certainly capable of proving the model invalid and seriously questioning the value of the theory.

That the model is at this point rudimentary cannot be denied. However, its form makes it readily amenable to refinement. The major refinement, which should be made as soon as possible, is the

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33. See, for example, Daedalus, v. 97, 1968, and David Victor Glass and D. E. C. Eversley (eds.), Population in History: Essays in Historical Demography (London: Edward Arnold, 1965).

establishment of an interdependence between the variables posited as decreasing mortality and fertility. At this point in time, there are only two indications of even the simplest interdependence displayed in the simulation model. These simple feedbacks occur in the DIET-TRANCOM cycle and the URBAN-INDUST cycle. Although it was felt that at this time it would be more valuable to consider all variables as dependent, independent or intervening, it is almost inconceivable that there are no relationships between interdependent variables in the scheme. This discrepancy should be minimized as soon as it is possible to do so, in order to improve the descriptive as well as predictive accuracy of the model.

The most powerful tool in determining the answers to the questions of interdependence, sequentiality, and time-span may well be the model itself. Inasmuch as these are empirical questions, the simulation has the advantage of reality if only because reality cannot be re-run, as can a computer program. Additionally, by its very structure the model is capable of undergoing shifts in levels of analysis. Because the variables selected for use in the model are superordinate classes of other variables, the transformation into a model of less abstraction such as the one put forward by Davis and Blake[34] in 1956 is straightforward. It is also not difficult to conceive of the

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34. Davis, Kingsley and Blake, Judith, "Social Structure and Fertility: An Analytical Framework," Economic Development and Cultural Change, v. 4, 1956, pp. 211-235.

formulation of the model in the more abstract terms of Duncan's ecological complex.[35]

Seventeen years ago, the president of the Population Association of America indicated the need for the development of demographic theory and assured members of the Association that even "he who develops a theory capable of being proved invalid makes a contribution."[36] The formal statement of transition theory herein, and the stochastic model which is its extension, are together an attempt to help remedy the situation. If the model is presumed to be an accurate representation of actual mortality and fertility declines and consequent population growth, then it can be used to predict the effects on the vital rates of changes in the independent and intervening variables. At this time, when the question of overpopulation is of crucial importance to the survival of mankind, the ability to predict the consequences for growth rates of innovations, be they technological, spiritual, or organizational, is of the utmost importance, and this ability would be no minor factor contributing to humanity's continued existence.

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35. Otis Dudley Duncan, "From Social Sytem to Ecosystem", Sociological Inquiry, v. 31, pp. 140-149.

35. Ruper Vance, op. cit.

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# APPENDICES

# APPENDIX A

## INVENTORY OF VARIABLES

## CONSIDERED TO AFFECT THE MORTALITY RATE

TABLE A1

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"POLITICAL STABILITY"

(ORDER)

| Author | Factor |
|---|---|
| Carr-Saunders | Political Security |
| Notestein | Domestic Order |
| Davis | Democratic Institutions |
| Blacker | General Security<br>Strong Central Political Control |
| Wrong | Political Unity |
| Coale and Hoover | Political Organization |

TABLE A2

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"IMPROVED RESOURCE EXTRACTION"

(AGTEX)

| Author | Factor |
|---|---|
| Thompson | Improvement of agricultural techniques |
| Carr-Saunders | Food production |
| Notestein | Improved farming methods<br>The New World and its resources |
| Davis | Improved agricultural techniques<br>Feasible commercial agriculture<br>New World resources<br>Agriculturalism |
| Blacker | Improved agricultural techniques |
| Wrong | Agricultural techniques |
| Cowgill | Mechanized agriculture<br>Viable commercial trade areas |
| Coale and Hoover | Market economy |

TABLE A3

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"IMPROVED FOOD SUPPLY AND DIET"

(DIET)

| Author | Factor |
|---|---|
| Carr-Saunders | Improved diet |
| Notestein | Available food supply |
| Davis | Regular, more abundant, food supply |
| Blacker | Regular, more abundant food supply |
| Wrong | Improved diet |
| Petersen | Improved diet |
| Coale and Hoover | Improved diet |

TABLE A4

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"IMPROVED TRANSPORTATION AND

COMMUNICATION NETWORK"

(TRANCOM)

| Author | Factor |
|---|---|
| Davis | Improved transportation network |
| Blacker | Improved transportation network |
| Wrong | Improved transportation network |
| Coale and Hoover | Improved transportation - communication network |

TABLE A5

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"IMPROVED PUBLIC SANITATION"

(SANTEX)

| Author | Factor |
|---|---|
| Thompson | Modern sanitation |
| Carr-Saunders | Sanitation techniques |
| Notestein | Sanitation |
| Davis | Public sanitation |
| Blacker | Elementary sanitation techniques |
| Wrong | Sanitation and public health |
| Petersen | Amelioration of environment |
| Coale and Hoover | Improved sanitation techniques |

TABLE A6

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"INCREASED MEDICAL TECHNOLOGY

AND IMPROVED MEDICAL CARE"

(MEDTEX)

| Author | Factor |
|---|---|
| Carr-Saunders | Modern medical techniques |
| Notestein | Modern medical techniques<br>Disease control |
| Davis | Scientific medical techniques |
| Blacker | Modern medical services |
| Wrong | Modern medical techniques |
| Cowgill | Scientific medical practice |
| Petersen | Change in balance between infecting organism and host<br>Preventive or curative therapy |
| Coale and Hoover | Improved medical techniques |

TABLE A7

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"MODERNIZATION"

(MODERN)

| Author | Factor |
|---|---|
| Thompson | Industrialization |
| Carr-Saunders | Clothing |
| Notestein | Industrialization<br>Productivity<br>Modernization<br>Level of living |
| Davis | Machinery<br>Scientific ideals<br>Humanitarian sentiments<br>Industrialism |
| Blacker | Regular source of fuel<br>Machinery |
| Cowgill | Industrialization<br>Mass education |
| Coale and Hoover | Economic development<br>Division of labour<br>Urbanization |

# APPENDIX B

## INVENTORY OF VARIABLES

## CONSIDERED TO AFFECT THE FERTILITY RATE

TABLE B1

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"CONTRACEPTIVE METHODS,

THEIR ACCESSIBILITY AND AVAILABILITY"

(OZ)

| Author | Factor |
|---|---|
| Thompson | Birth control |
| Carr-Saunders | Birth control techniques |
| Coale and Hoover | Contraceptive techniques |
| Robinson | Fertility control by choice |

TABLE B2

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"TRADITIONAL VALUE SYSTEM

PREDISPOSED TO HIGH FERTILITY"

(CUSTOM)

| Author | Factor |
|---|---|
| Notestein | Traditional home-centred family life<br>Preservation of the family<br>Survival of the group |
| Davis | Large family system |
| Coale and Hoover | Family as a productive unit<br>Advantages of the large family<br>Traditional customs and beliefs |
| Petersen | Traditional cultural norms<br>Traditional magical norms<br>Traditional religious norms<br>High age at marriage<br>Low proportion of married adults<br>Little remarriage of widows<br>Low frequency of marital intercourse |

TABLE B3

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"URBANIZATION"

(URBAN)

| Author | Factor |
|---|---|
| Notestein | Urbanization |
| Davis | Urbanization |
| Blacker | Urbanization |
| Coale and Hoover | Urbanization |

TABLE B4

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"INDUSTRIALIZATION"

(INDUST)

| Author | Factor |
|---|---|
| Carr-Saunders | Urban industrialism |
| Notestein | Industrialization<br>Factory system<br>Commerce |
| Blacker | Industrialization |
| Coale and Hoover | Economic development |

TABLE B5

VARIABLES CONSIDERED TO AFFECT OR SUBSUMED

BY

"MODERNIZATION"

(MOD)

| Author | Factor |
|---|---|
| Carr-Saunders | Small family system |
| Notestein | Individualism<br>Rising aspirations<br>Educational system<br>Welfare of individual child<br>Protection of individual |
| Davis | Individualism |
| Kirk | Rising aspirations<br>Desire to limit family size |
| Hatt, Farr, and Weinstein | Modernization |
| van Nort | Cost of children |
| Petersen | Declining average family size |
| Robinson | Modern living pattern<br>New value system |