difficult to explain why high rates of arteriosclerotic heart disease and malignant neoplasms are strongly associated with high suicide rates in urban areas, or why in most areas widowed persons have higher death rates than single, married, or divorced persons of the same age (Dodge and Martin 1970, p. 9).

The role of social stress as a factor in human health is by no means widely recognized by the medical profession or fully established by experiment. Still less certain is the association between social stress and crowding. Most authors agree that, although crowding is statistically correlated with high death rates from chronic or degenerative diseases, crowding per se may not be the causal factor but, rather, the perception of crowding. In other words, the crowding that may lead to a breakdown of an individual's resistance to disease may be related to that individual's past experience and to his present value system, in relation to the present value system of the crowded area in which he lives. According to Calhoun (1970, p. 117), "Crowding thus must also be assessed on the basis of degree of harmony among the held values of the individuals who are sufficiently contiguous to be aware of each other's presence."

Thus a dynamic model of the effect of crowding on human life expectancy through social stress might include an input from rate of change of crowding. According to this model a negative contribution to the aggregate health of a population would occur when the crowding change rate becomes greater than the time necessary to readjust living conditions and personal expectations to new degrees of crowding (Figure 2-44).

> . . . the relatively simplistic notion that crowding exerts its deleterious effects solely through facilitating the interpersonal spread of disease agents is no longer adequate to explain the known phenomena. A more appropriate formulation would seem feasible if we recognize that increased population density increases the importance of the social environment as a determinant of physiological response to various stimuli, including potentially disease-producing agents; that within this social environment the quality of social interactions and position within the group seem to be important factors; and that, given time, adaptation to these social changes can and does occur, but the newcomers to the situation will always be the segment of the population at highest risk. [Cassel 1971, p. 475]

Figure 2-44 Influence of crowding on life expectancy through social stress

5. Crowding in World3. A thorough representation of the complicated effects of crowding on human health should probably include all the structures proposed here, and perhaps some other factors as well. Such a detailed crowding factor would not be appropriate for World3, given the poor quality of the data available and the low level of detail in other sectors. On the other hand, urbanization and increasing population density appear to be such important factors in the world situation that they should not be completely ignored in a representation of long-term global trends. In 1900, 11 cities in the world had populations exceeding 1 million; in 1950 there were 75; in 1985 there will probably be 273 (U. N. 1972*b*). Therefore, we attempted to include a crowding effect in the world model, but with as few variables as possible. In doing so we may have lost some important short-term dynamic behavior, but we are only interested here in the possible long-term impact of increasing urbanization and population density on global population growth.

The causal structure of the crowding influence in World3 is shown in Figure 2-45. We made crowding a function not only of total population, reflecting the spread of infectious diseases, but also of industrialization, reflecting both the positive health effect of industrialization on the prevention of those diseases and the negative health effect of large industrial cities through exposure to pollution and stress. A detailed discussion of the assumptions behind this structure and its quantification follows.

As Figure 2-45 indicates, crowding in World3 is represented by the fraction of the population living in urban areas. Thus by crowding we actually mean urbanization, defined not as the absolute number of people in cities but as the proportion of the total population in cities. A nation may have growing cities, but its urbanization does not increase unless the population of its cities is growing faster than its rural population.

There are two possible causes for increasing global urbanization. Historically, the formation and the growth of cities in different nations have been closely related to

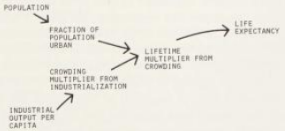

Figure 2-45 Influence of crowding on life expectancy as represented in World3