speculation than for logical projection on the basis of any generally accepted body of theory. We chose to represent unprecedented value changes by a set of switches throughout the equations of the model, which the operator can use to express his own hypotheses about future social development.

Ecological and Technological Assumptions

Proponents of either the ecological or the technological world view may argue that the structural assumptions of World3 are biased against their position because World3 includes the basic assumptions of the other side. Physical limits to material growth are indeed represented in the model: depletable resources are brought into the production function, and diminishing returns to physical inputs are considered inevitable. When viewed from the perspectives afforded by the technological model of man, these assumptions appear to be heretically Malthusian. Those subscribing to the technological mental model may fear that assumptions like those in World3 will engender a pessimism that will block mankind from pursuing feasible solutions to the problems caused by growth.

On the other hand, we assumed in World3 that cultivatable land, agricultural yields, and resource reserves are greatly expandable by technological improvements yet to come. We also assumed that perfectly effective birth control and the production of energy from nondepletable sources are achievable, that demographic transition will always accompany industrialization, and that human material desires are satiable. This set of assumptions may be totally unacceptable to those who accept the ecological image of the world. They may believe that important physical limits have already been exceeded and that the model irresponsibly exaggerates the options available to global society and will further postpone corrective actions that are long overdue. They may also believe that the physical limits to growth will in practice be much lower than those suggested by World3 since social factors that produce drastic misuse of resources, such as international conflict, erosion of mental health, greed, or the inability to manage increasingly complex systems, are not included in the model.

The debate between ecologists and technologists on the nature of the world appears to be similar to that on the nature of elephants by the blind men, each of whom perceived only a part of the whole. In World3 we tried to provide a set of structural assumptions that would be general enough to include both points of view, because we recognized partial validity in each extreme. The model structure represents both man's adaptability and the earth's physical limits. Various assumptions about their relative importance can be tested, not by changing the model's structural assumptions but by changing the parameters that express quantitatively the effectiveness of technologies, the position of limits, and the nature of social choice.

1.8 ESTIMATION OF MODEL PARAMETERS

The network of interlocking feedback loops defined by the structural assumptions constitutes the skeleton of the model, the framework upon which all further

analysis depends. System dynamics places primary emphasis on determining this model structure, rather than on estimating numerical parameters, for three reasons. First, experience in modeling feedback systems rapidly demonstrates that even the most sophisticated numerical estimation techniques will not produce useful conclusions from a faulty or incomplete model structure. Second, system dynamics models are usually concerned with imprecise questions about the general behavioral tendencies of social systems. Third, a correct causal structure generally produces realistic model behavior, even with only approximate numerical parameters.

Since this primary focus on the formulation of causal structure rather than on the estimation of parameter values differs markedly from the relative emphasis in several other modeling techniques, we shall describe in some detail the role of quantitative data in system dynamics models in general and in World3 in particular.

The Spectrum of Available Information

The observations mankind has assembled about the world vary greatly in form, accuracy, and precision. Some numerical information that is both accurate and precise has been gathered by scientific measurements carried out on carefully controlled physical systems. Examples of this kind of information include graphs of the boiling point of water as a function of pressure, tables of tides and the motion of planets, and measurements of the speed of light. Such information forms the basis for most models in the natural and engineering sciences, but it constitutes only a small fraction of total human knowledge.

A second body of knowledge, inherently less accurate but more comprehensive in its coverage, takes the form of statistical data on complex, uncontrolled social systems. Examples include census reports, economic indicators, and the results of opinion polls. The precision of this information varies widely. Inexpensive data processing and storage procedures have permitted the acquisition of large quantities of statistical information, and growing data banks provide quantitative inputs to most models in the social sciences. However, all the social data banks combined contain only a small portion of the information that people have acquired through observations of the world around them.

The least precise but most comprehensive information available is that acquired through direct individual and group experience. It is typically expressed in the form of intuitive guess, expert opinion, or group consensus. Although this information also varies greatly in accuracy, is generally nonquantitative, and is seldom communicated clearly, it provides the basis for most mental models and nearly all human decisions. Some examples are a voter's personal opinion about the relative honesty of two politicians, an analyst's projection of the stock market's response to a prolonged energy shortage, or a board of directors' consensus about which new product will most enhance its company's profits.

System dynamics is primarily a technique for simulating social systems, and its users are working to understand the possible behavior patterns of a total system rather than to predict the precise future value of a specific variable. Therefore, the method emphasizes using the most comprehensive available information, however precise, in the belief that social systems are often guided by human perceptions, biases, goals,