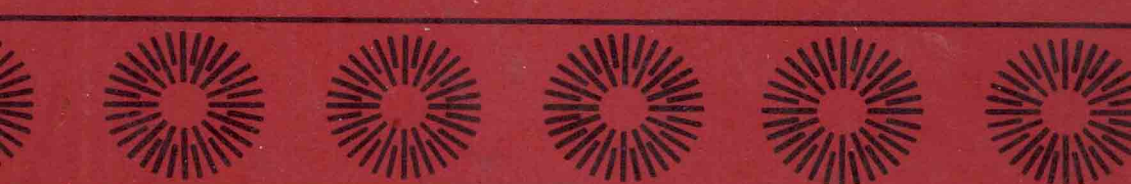
World Modeling

Barry B. Hughes



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The Mesarovic·Pestel World Model in the Context of Its Contemporaries

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Preface and Acknowledgments

This book is in many respects a progress report on seven years of work by a great many people. Mihajlo Mesarovic and Eduard Pestel began in 1972 to plan for the construction of a computer simulation or model that would represent major global development processes and allow analysis of what the Club of Rome calls the *problématique.* They began in early 1973 to organize teams in Cleveland and Hannover. Through my introduction to Mesarovic by John Richardson, and because of my great excitement about the work, I became one of the original members of the modeling group and one of the few who have participated in the entire effort.

After seven years I still remain excited by the work. Although we have by no means solved to our complete satisfaction all the modeling problems that have faced us, much less resolved the major issues of the *problématique,* I believe that we have made important contributions—both to the science and to the public debate. The purpose of this book is to allow others to assess the scientific merits of the work.

It is impossible to recognize appropriately all the hundreds of individuals and organizations who have contributed to this work. Mesarovic and Pestel together initiated, organized, and directed the effort through 1974, after which the primary burden fell upon Mesarovic and the Cleveland team. Among other team members who have worked on the project the longest and contributed the most are Aldo Barsotti, John Richardson, Thomas Shook, and Patricia Strauch. A personal debt of gratitude is owed to the George Gund Foundation for a grant that allowed the writing of this book. Thanks are due also to Mary Lou Cantini and Wanda Reeves for expert typing.

Finally, I should add the traditional disclaimer of responsibility for this book by anyone else. In this case it can be made more specific. Although I have tried to present faithfully the second-generation Mesarovic-Pestel model (WIM), in representing the work of so many others besides myself some errors of representation and some omissions are inevitable. For those I take full responsibility.

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1 Introduction

The purpose of this book is to document the World Integrated Model (WIM). That model is the most recent generation of the Mesarovic-Pestel world model, the global computer model which was the underpinning for the second report to the Club of Rome. The documentation will fully present the structure and equations of the model. It will outline the data base and validation procedures used in model development. Almost as important as these activities, a documentation effort must identify the position of any scientific work within the cumulative body of scientific effort. We shall therefore also review appropriate prior and contemporary modeling activities, both those which have similarly focused on long-term global development patterns and those which, though more limited geographically or temporally, are related or relevant.

History of World Integrated Model Project

Any history of the project must begin with the Club of Rome. That body identified, at the time of its formation in 1968 and under the leadership of Aurelio Peccei, a *problématique* (Peccei, 1977). The *problématique* was defined as a complex of interrelated problems: the recent growth and apparent persistence of a major gap in living standard between the richest and poorest people; the shrinking nonrenewable resource base of the globe; the increasing interrelatedness of issue areas once perceived to be self-contained; mankind's ever-growing ability to affect its larger environment in frequently unanticipated and undesirable ways; and the inability of current social and political institutions to deal with these problems. The Club of Rome thus established among its purposes the development of tools by which the *problématique* could be better understood and with which mankind could face the challenges presented by it.

The Club of Rome, itself neither a research institution nor a funding source, undertook to support these developments through the mechanism of selecting and publicizing reports delivered to it. It recognized early the potential of the systems dynamics approach of Jay Forrester. With the good offices of Forrester, a project was undertaken to expand upon the work of his *World Dynamics* (1971), to develop a computer model called World 3, and to present, as a report to the Club of Rome, the *Limits to Growth* (Meadows et al., 1972). The power of the Meadows team's book and its timing, immediately prior to global agricultural and energy crises in 1973, combined to give it tremendous readership,

particularly in Europe, and to stamp an image of the Club of Rome upon the minds of a wide public—an image which largely still prevails even in the face of considerable diversity within the organization and subsequent reports to the body which differ markedly from the first.

Mesarovic and Pestel met at the Massachusetts Institute of Technology (MIT) while the former was lecturing there on multilevel hierarchical systems theory and the latter was reviewing progress of the World 3 model development efforts on behalf of the Club of Rome. They anticipated a number of the criticisms which the scientific community would later direct at the *Limits to Growth,* including its holistic treatment of the world, high level of variable aggregation, and absence of social and political mechanisms which act to resolve problems and to control global systems before the systems reach points where only collapse is possible. Thus they published a conceptual foundation for an entirely different global model (Mesarovic and Pestel, 1972).

In the spring of 1972 at their respective academic institutions, Case Western Reserve University and the Hannover Technische Universitat, Mesarovic and Pestel organized two teams to create the new global model. The teams incorporated individuals from the social sciences and scientific and technical fields in a major interdisciplinary effort. The first preliminary modeling effort was presented at the Club of Rome meeting outside Paris in January 1973. In July 1973 a conference of economists was held at Reisenburg, Germany, to review the structure of the economic submodel. Although the early model was a representation of only one region, it incorporated some of the features which have been stressed within the project since its inception. For instance, the model represented a number of policy variables and parameters which could be manipulated easily by the model user in testing alternative scenarios about future developments.

The first "public" presentation of the Mesarovic-Pestel world model came early in 1974. In April a seminar was organized at the Woodrow Wilson International Center for Scholars in Washington, D.C., to announce the completion of a model and to present the first results of analyses with it. A similar meeting was held at Haus Rissen in Hamburg, Germany. A large scientific meeting at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria, followed in May 1974. Nearly thirty papers documenting the full range of the modeling effort were presented. The six-volume set of reports collected from that meeting (IIASA, 1974*b*) has served as the primary source of scientific documentation on the project since that time.

In late 1974 Mesarovic and Pestel published *Mankind at the Turning Point* (1974), describing the model for a nonscientific audience and presenting a wide range of analyses made with it. That book constituted the second report to the Club of Rome and sold heavily throughout the world.

The Mesarovic-Pestel project did not end with the work documented at IIASA or described in the second report. Work under the leadership of Mesarovic

continued without interruption on the next generation of model, labeled the World Integrated Model (WIM). These efforts have stressed the creation of a policy analysis tool, a computer simulation with two basic characteristics: simplicity of use so that anyone with motivation can begin using the system within hours; and incorporation of sufficient detail and policy content so that policy decision makers and their staffs will be motivated to use the tool. As an integral part of that development process, seminars have been organized around the world in which national government officials and representatives of international organizations have interacted with the WIM system (model and interactive computer software) throughout the process of development. These seminars, lasting from half a day to a week, include (but are by no means limited to):

Selected European parliamentarians, Hannover, Germany, February 1975.

Prime Minister and selected ministers of Iran, in Tehran, June 1975.

Prime Minister and minister of planning of Egypt, in Cairo, April 1976.

Selected congressmen, congressional staff, and the U.S. accountant general, at the General Accounting Office, Washington, July 1976.

Selected United Nations delegates and UNESCO officials, in Seminar on the New Economic Order, New York, January 1977.

Selected officials of the Economic Research Service, U.S. Department of Agriculture, Washington, January 1977.

Representatives of planning organizations throughout the Pacific region, at Presidential Seminar of the East-West Center, Honolulu, January 1977.

Members of the Department of Transportation in Washington, March 1977.

Representatives of the National Planning Institute of India, New Delhi, April 1977.

Members of the Provincial Government in Toronto, Canada, May 1977.

Minister of Industry and representatives from the President's Office in Dakar, Senegal, July 1977.

Members of the National Academy of Sciences, in Moscow, August 1977.

Prime Ministers of Sweden and Norway and the President of Senegal, in Stockholm, September 1977.

Various Foreign Ministers from African, Caribbean, and Pacific (ACP) countries and the Prime Minister of Fiji, at the European Community Commission meeting on the Lome Convention, Brussels, March 1978.

Representatives of UNICEF at Harvard University, July 1978.

The model development and seminar process has been accompanied by some published and many nonpublished analyses using the model. The published studies include analysis of (1) U.S. energy options in the global system, (2) the energy scenarios presented by Wilson's Workshop on Alternative Energy Strategies, (3) probable global developments in key issue areas through the end of the century, (4) the Hudson Institute Scenarios of Herman Kahn, and (5) development problems in Africa (Hughes and Mesarovic, 1977, 1978*a*, 1978*b*, and 1978*c*; Hughes and Strauch, 1979).

Since collection of the IIASA reports, there has been little published work documenting the structure of the developing model. There have been some relatively widely distributed internal reports, including Dayal's (1976) presentation of model equations, Hughes's (1977*a* and 1977*b*) presentations of flowcharts for the model and a complete description of the computer program, and Strauch's description of the computer program (Strauch, 1978). In spite of these efforts, however, it is clearly time for a thorough documentation in the published literature of the current version of WIM. That is the purpose of this book.

Structure of the Book

It is necessary to place WIM into a more general modeling tradition. This book therefore both documents WIM and provides a quite comprehensive review of global modeling literature. Early in the work it was discovered that a presentation of WIM which simultaneously compared and contrasted it with other work overly disrupted the presentation of the model. Yet a complete presentation of WIM followed or preceded by a discussion of other modeling efforts makes comparison and contrast very difficult. The solution is a compromise, specifically a sequential presentation of major WIM submodels, each preceded by a discussion of relevant literature.

One of the major failings of large-scale model documentation, however, has been inadequate overview of the entire effort and insufficient description of the relationships among model units. Thus two chapters precede our segmented documentation of WIM submodels. The first introduces the spectrum of global models and discusses major issues in world modeling generally, while the second describes the WIM treatment of these major issues.

Thus the next chapter focuses on other global models. It first introduces the models and then discusses major issues in global modeling. Many of these issues concern the scope and level of aggregation. For instance, modelers must decide on the geographic scope and on the number and nature of geographic regions to be represented, if any. They must determine the substantive scope of the issue areas and the human or physical systems to be represented and the level of detail with which each should be represented. Similarly, decisions must be made on temporal scope (how much future and how much past to represent) and the

appropriate time interval for the model. There are other important structural issues besides scope. For instance, there are a variety of procedures for reaching equilibrium between demand and supply, a central issue not only for economic submodels but for other submodels such as energy or agriculture. Dynamics can also be treated in many different ways. Similarly, critical issues surround the procedures for linking and integrating major subunits within models.

Whereas chapter 2 reviews these major structural issues and their treatment in other large-scale modeling efforts, chapter 3 focuses on their treatment in WIM. Chapter 4 begins the presentation of WIM submodels by describing the population submodel, preceded by a general discussion of population modeling. Chapters 5 through 9 continue the WIM documentation of economic, energy, agricultural, raw materials, machinery, and trade submodels. In each case, a discussion of approaches taken by others serves as an introduction to the presentation of the WIM approach.

Chapter 10 presents an overview of the data sources used in the model, and the parameter estimation and validation procedures used. Chapter 11 introduces the reader to some of the analyses that have been performed with the model in the context of a more general discussion of its scenario analysis capabilities. Chapter 12 returns to general issues of world modeling.

It is an unfortunate truth that documentation of models has always served two purposes. The first is accurate scientific description so that others can judge the quality of the work, and in the scientific tradition, can build upon it. The second is advocacy rather than description. It is nearly impossible to be completely objective when reporting upon work done with much dedication over a long period of time. This has manifested itself in much world and other computer model documentation primarily in errors of omission. Given the natural tendency to focus on what is new, unique, or better, the less original and less profound procedures or equations sometimes slip through the cracks. Thus readers of documentation often finish their tasks with a sense of incompleteness. The tendency toward incompleteness is abetted by the interdisciplinary and team nature of these projects. Often portions of documentation are written by different team members, perhaps even from different perspectives, and some aspects of the model (perhaps even the integration of the components described) fail to receive attention. Still another problem is that ongoing research projects in the modeling area are constantly updating and improving the models. Thus precise documentation may be in some cases misleading simply because by the time it reaches print the structure it describes has been supplanted. This further reinforces tendencies toward incompleteness since authors anticipate that many major model weaknesses will no longer exist when the documentation is published.

Although there is no way to be free of these influences, they can be minimized. First, this description is individually not collectively authored. Second, the presentation is from the general to the specific. Looking at how other models deal with major issues and represent key components provides the most general

context. Then the description of WIM itself proceeds from general concerns to basic structures to specific equations. Third, this book seeks to be full and complete documentation of the World Integrated Model at a specific time, namely, January 1, 1979.

2 World Model Issues

This chapter and portions of chapters 4 through 9 review global modeling approaches other than the World Integrated Model (WIM). They examine a variety of models. These include the models normally recognized as multiple-issue global simulations, ranging from the Forrester-Meadows models to Leontief's United Nations model. Because this is a review of *approaches* and not just of specific models, we shall also refer widely to more specialized and generally one-issue models and one-country models. Clearly, world models themselves must be considered in the context of a wider modeling environment.

The approach here is more comparative than evaluative. The various world models (and other models) emphasize issue areas or components to different degrees and represent them with different levels of complexity. The desire here is not to judge the models on the basis of inclusion or exclusion of various elements, nor to judge them on the basis of approach to various problems, but rather to discuss the range of approaches taken and to indicate how different models treat common problems. In many cases evaluative judgments will be apparent, for instance, when models fail to include an obviously relevant component or when other models use a clearly superior approach.

This chapter discusses the major models in terms of general structural characteristics. In the first section we consider issues of scope: the number and type of geographic units represented, the number and type of substantive units or issue areas within the model, and the time horizon. In the next section we turn to treatment of the basic methodological issues faced by large-scale models: procedures for integrating major submodels, mechanisms for achieving equilibrium with submodels between demand and supply, and treatment of dynamics. The next chapter presents WIM with a completely parallel structure.

It should be useful to comment on other relevant model reviews. Perhaps the single most detailed review was done of the World 3 model by a group at Sussex, England, under the direction of Cole (1973). The group members discussed at some length various structural assumptions, data values, parameter estimations, and conclusions of the Meadows group. Cole also authored or coauthored a number of subsequent reviews of global models more generally (1974 and 1977). A listing of model attributes with some discussion was also made for the Subcommittee on Fisheries and Wildlife Conservation and the Environment (1976). Although it says little about most of the models discussed here, an excellent comparative overview of the modeling methodology can be found in Greenberger et al. (1976). A review focusing primarily upon political and social models

or those aspects of larger models is that of Deutsch et al. (1977). A very extensive review of global models has been undertaken by the Interfutures project of the Organization for Economic Cooperation and Development (OECD). A recent review was done by the Systems Research Institute in Pune, India (Sundaram and Krishnayya, 1979). In general, the model reviews have been nontechnical or semitechnical. That is, they have focused primarily on scope, general structure, and basic methodologies of the models. Partly this is attributable to the inadequate documentation of many of the models, and partly it is explainable by the short elapsed time since the appearance of the models.

The best review of major global models is by Richardson (1977). Frequently the most useful reviews are of a more restricted set of models such as the annual energy model reviews at IIASA (Charpentier, 1975; Beaujean and Charpentier, 1978), an excellent comparison of a handful of energy models by Brock and Nesbitt (1977), the review of agricultural models by Meadows (1977), and the extensive survey of agricultural models by the U.S. General Accounting Office (1977).

The Models and Their Scope

In general the review of models other than WIM throughout this book does not follow the traditional sequence of discussing one model at a time. Instead it focuses on modeling problems or model components common to many efforts, and discusses alternative approaches taken to the problems or components, using specific models as illustration. The exception is this section, which first introduces the major global models and summarizes their scope. The scope of the models discussed is shown in table 2-1.

One of the very first global models is that of project LINK (Ball, 1973). Project LINK was conceived in 1968 and the system has been developed and improved continually since then. Project LINK is a response to the necessity for having an international context for national economic models. It is in fact a linkage among a variety of country and regional models. Currently the models included represent thirteen OECD countries, seven Council of Mutual Economic Assistance (CMEA) countries, four regional less-developed country groupings (Africa, Latin America, the Mideast, and South Asia), and a residual grouping (Klein and Su, 1979).

The country and regional models vary in structure, and relatively simple gross national national product (GNP) account models have been used at times prior to the development of full econometric models. The models vary in complexity up to the U.S. model (of the Wharton School) with its 514 endogenous and 282 exogenous variables. The trade structure of LINK is somewhat simpler with four trade categories: food, beverages, and tobacco; raw materials (nonfuel); fuel; and manufactures and semimanufactures. The projections made with the

Table 2-1
Major Global Models and Their Scope

	Link	*Forrester-Meadows*	*WIM*
Geography	25 regions (13 OECD and 7 CMEA)	1 world	12 regions (5 subregions of any region)
Time horizon	3 years	1900–2100	1975–2025
Substantive areas	Economy structure variable by region Trade (4 categories)	Economy (3 sectors) Population (4 cohorts) Agriculture Resources Environment	Economy (7 sectors) Population (86 cohorts) Energy (5 categories) Food (5 categories) Materials (3 categories) Labor/Education (4 categories) Machinery Aid/Loans Trade (15 categories) Relative prices

	Bariloche	*Fugi*	*Leontief*	*Sarum*
Geography	4 regions (3 LDC regions)	9–15 regions	15 regions	3 strata
Time horizon	1960–2060	1975–1985	1970–2000 (10 year increments)	1968–2018 (2 month increments)
Substantive areas	Economy (5 sectors) Population and health Food (3 categories) Urbanization and housing Education Trade (3 categories)	Economy (14 I/O sectors) Mineral resources	Economy (48 I/O sectors of which: Food–4 Mineral, Energy–9 Manufacturing–22 Pollutants–8) Trade (40 categories) Relative prices	Economy (13 sectors, of which: Food–8)

LINK system are generally short term, running three years into the future, but can also be medium term, running another three to eight years (Klein, 1976*b:* 12). Some country models are quarterly and others are annual. The LINK system itself produces forecasts on a one-year cycle; that is, forecasts are produced in an iterative process and a three-year forecast is produced every year.