

**The Threshold 21  
Sustainable Development Model**

by

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**Abstract**

As we approach the turn of the millennium and pass the 50th anniversary of the Breton Woods and United Nations institutions, none of our major development agencies have a comprehensive sustainable development model. The Millennium Institute, after a decade of assisting countries in long-term sustainable development studies, has developed a multidisciplinary national sustainable development model called Threshold 21®.<sup>1</sup> The model integrates economic production, national accounts, demography, agriculture, energy, health, education, nutrition, and environment in a single model based on the principles and methodology of systems dynamics. It simulates the dynamic interactions of these variables for a period of 50 years. Threshold 21 is written in the Vensim®<sup>2</sup> simulation environment. The model is being applied first in an analysis of alternative futures for Bangladesh. The Millennium Institute, in collaboration with development partners, is planning applications in several countries, including Australia, China, and the United States.

**I. History**

The Threshold 21 Sustainable Development Model is the culmination of more than a decade of work by the Millennium Institute in collecting and studying models of specific sectors (energy, environment, agriculture, demography, health, education, economy, industry, natural resources, politics, rural and urban development, and transportation) that could be integrated into a single, inter-related, interacting dynamic national sustainable development model. The Institute now has a library of more than 300 such models. A description of some of the most interesting and useful models in the Institute's collection has been published. (Barney 1991).

The overall purpose of the Institute's modeling effort is to develop a global model, the *MILLENNIUM EARTH MODEL* (MEM) that links national sustainable development models for every country. Threshold 21 is the prototype national sector for use in the overall *MILLENNIUM EARTH MODEL*. The MEM will integrate all of the national models and provide projections on the future of the whole planet based on the actual plans of all countries.

The purposes of Threshold 21 and the MEM are to:

- build consensus on common goals and actions based on a shared understanding of the synergy among all sectors of society at the provincial, country, and global levels

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<sup>1</sup> Threshold 21 is a registered trade mark of Millennium Institute.

<sup>2</sup> Vensim is a registered trade mark of Ventana Systems, Inc.

- anticipate developments resulting from the implementation of specific policies and programs and forge consensus on appropriate strategies
- influence real-world policies and actions through clear and persuasive analyses
- optimize the use of available resources to build a healthy future.

The Institute's strategy for building these models is to proceed in stages, focusing first on the country-level model Threshold 21. This model is now in a proof-of-concept version which links, at a high level of generality, many factors involved in national development. Even in this version, Threshold 21 provides an integrated overview of the varied and complex interplay of these factors in the dynamics of development. Individual sectors are being articulated in greater detail through applications in specific countries.

Threshold 21 is a Systems Dynamics model (Forrester 1973) built with strict adherence to causality and fully recognizing the dynamic nature of the national development problem. This methodology permits high standards to be maintained while integrating a wide range of models for different sectors. To facilitate this integration and manage analysis and presentation, the model has been developed in Vensim (Ventana Systems, Inc. 1994).

Sectors in Threshold 21 are based on model structures that have been tested and well-established in the various fields. For example, the food and nutrition sector of Threshold 21 is patterned on the Food Needs Analysis (FNA) model developed by the Department of Agriculture of the United States (US Department of Agriculture 1985), and the national accounts sector is based on the World Bank's Revised Minimum Standard Model (RMSM) (Mills 1992).

Threshold 21 now includes approximately 800 variables in the following major sectors which are dynamically linked to each other: demographics, agricultural production, health care, food and nutrition, international trade, national accounts, social services, energy and energy efficiency, goods production, education, and environment. It requires a PC running Windows 3.1 or higher and the Vensim simulation environment available from Ventana Systems. Hardware requirements are a 386 or higher processor, 20 MB hard disk space, and 8 MB RAM.

## **II. Overall Design of Threshold 21**

Threshold 21 uses a modular design. Inputs and outputs required of each sector are carefully specified. As long as these specifications are met, sectors can be removed, developed further, applied independently, and replaced in the overall Threshold 21 model. Individual sectors can be as elaborate (or simple) as desired by individual users. The sectors must, however, provide all of the specified outputs and accept all of the specified inputs called for in the overall design.

This approach was successfully implemented in developing the country-specific model *Bangladesh: Threshold 21*. To address specific issues in a particular country it may be necessary to articulate one or more sectors in more detail than they are articulated in the proof-of-concept model. In Threshold 21 this is accomplished by replacing the sector from the proof-of-concept model with a more completely articulated version of the same sector. Threshold 21 provides for a fixed set of interface points between each sector and the rest of the model, regardless of the level of detail or complexity within the sector. Individual sectors can be separated out of Threshold 21, modified independently, and then re-inserted back.



Bangladeshi children in the future cannot be met without a comprehensive understanding of how overall sustainable development can occur for Bangladesh.

Of particular concern to the leadership of UNICEF-Dhaka was the perception that, as in many countries, there is an inadequate consensus among the political, business, governmental, academic, spiritual, media, non-governmental leaders of Bangladesh about paths toward a sustainable future. The donor community, too, was lacking the consensus necessary for adequate coordination and cooperation. As an experimental step toward building consensus, UNICEF-Dhaka wanted a computer model of Bangladesh which covered the wide range of issues involved in achieving sustainable development. The hope was that such a system might be used to increase the level of agreement and understanding among the country's leaders and donors, and that a plan or process might emerge that would have solid commitment and support of everyone necessary for sustained progress toward sustainable development for the present and future generations of Bangladeshis.

With this overall objective in mind, the following tasks were identified to adapt the proof-of-concept version of Threshold 21 to Bangladesh.

1. Formulate the best available complete hypothesis (formalized mental model) of how the country of Bangladesh functions in a form that allows: (a) testing against alternative hypotheses (mental models) and (b) comparison with available data.
2. Demonstrate the usefulness of the model by entering the appropriate data and comparing the model's results with historical data.
3. Improve understanding of the whole system beyond the sum of the available mental models.
4. Begin projecting future trends.
5. Begin analyzing consequences of alternative policies, and
6. Begin developing consensus on the best path to the future.

The process of formulating *Bangladesh: Threshold 21* followed directly from the purpose of the model. It started from the proof-of-concept model of Threshold 21 and consisted of the following steps:

1. Modification of sectors in the proof-of-concept model of Threshold 21 to match actual conditions of Bangladesh. This meant, in particular, the addition of human development sectors dealing with health care, education, and nutrition. Other more modest changes were needed to adapt the model to unique characteristics of Bangladesh. For example, in Bangladesh the primary school covers five grades only, and no feed grains are used in animal husbandry.
2. Insertion of data for Bangladesh into the model. Sources of data included: The STARS Database of the World Bank, the Sex and Age Distributions of Population from the United Nations, the 1992 Statistical Yearbook of Bangladesh, the DISIDE Database of UNICEF, Bangladesh, and other publications and personal communications. (World Bank 1994; United Nations 1991; Khan 1994)
3. Comparing the simulated history of Bangladesh with existing time-series data for Bangladesh. The *Bangladesh: Threshold 21* was initialized to 1965 and simulated for the period 1965-1995. The simulation results were compared with the existing data series.
4. Adjusting the parameters of the model to match the time-series data for Bangladesh. Discrepancies between the simulation results and the time-series data were noted and causes of discrepancies traced. Often it was necessary to trace the causes of discrepancies through

many interacting variables and feedback loops because in many instances the root cause of the behavior of a variable is far removed from the variable itself. This work was greatly facilitated by an array of powerful analysts' tools available in Vensim. Once the causes of the discrepancies were identified, the discrepancies were eliminated / reduced by modifying constants and predefined non-linear response functions.

5. Altering the model structure as needed. In the event of persistent and wide mismatch, between model generated consequences and historical data, the model structure was altered by modifying equations and adding or deleting variables. (The effects of wars, cyclones, and floods were either ignored or be accounted for through exogenous inputs.)
6. Examining the model's behavior under extreme conditions. Models should be able to produce plausible results even at extreme conditions, and when they do not, it is important to explore why. In the case of *Bangladesh: Threshold 21*, the model was tested with a wide range of extreme policy inputs. In several cases, implausible behavior was found and appropriate changes were made.
7. Presenting the model to experts on Bangladesh. Finally, the model was presented to real experts on Bangladesh—the Bangladeshis themselves—to see if the model structure matches their knowledge of the actual structure and if the data and parameters match the ones that they know. This process began in January 1995 when a ten-day technical training program on *Bangladesh: Threshold 21* was held near Dhaka. Twenty two people from Bangladeshi Government Agencies, non-government organizations, and Dhaka offices of UN and other international agencies participated.

#### **IV. Preliminary Results of *Bangladesh: Threshold 21***

Threshold 21 is designed to explore scenarios under which policy choices would influence public and private investments among the sectors of the economy, social services, and environmental protection. The model has an internal algorithm which guarantees the zero sum of production and imports less investments, consumption, and exports.

The following conclusions are based on early analysis by the authors. They do not represent the opinion of UNICEF or the Government of Bangladesh. Further testing and modifications of the model will occur during 1995

The simulations of many alternative investment strategies show the future of Bangladesh dividing into two phases. The phases separate somewhere in the 2030-2040 period.

##### **Phase 1: 1995-2030**

- In phase 1, it is possible to change future trends by shifting investments among different sectors. More investment in social services and thereby better family planning programs, better quality of education, better health care and higher productivity combine to slow population growth rates and generate many synergistic benefits, including the acceleration of economic growth and positive impacts on quality of life indicators. More direct investment in goods production generates higher GNP, which also produces many synergistic benefits but generates more pollutants too. More investment in agriculture directly increases agricultural production, and more investment in environment sector directly reduces pollution intensity; both of these investments produce synergistic benefits, too. A variety of policies therefore, may stimulate general improvements in phase 1.

### Some specifics

- \* Population is most likely to rise to a size between 175 to 200 million before leveling off and then declining. But in some scenarios where social sector investments are slashed, population could exceed 240 million, unless checked by extremely unfortunate conditions.
- \* In several scenarios, per capita calorie intake does not grow but slowly declines.
- \* In several scenarios per capita goods consumption grows until about 2040 and then levels off.
- \* Generally pollution intensity grows considerably.

### Phase 2: 2030-2040 and beyond

- During 2030 to 2040 period many interacting factors come in play that make further progress difficult. This development is found in almost all policy simulation in phase 1. In fact deteriorating conditions are observed in many scenarios. The factors involved include population, pollution, limits to available farm land, limits to foreign exchange reserves and environmental and financial costs of intensive agriculture.

The simulations suggest that the ease with which Bangladesh moves through the 2030-2040 period and beyond depends greatly on the leaders of Bangladesh and the world community making thoughtful and synergistically effective investments and policies during the 1995-2015 period. With careful preparations, Bangladesh should be able to move beyond the difficult 2030-2040 period into a period of stable or declining population and sustained improvement of general conditions.

### V. Next Steps

Parts of the Government of Bangladesh, including the Ministry of Planning and the Bangladesh Bureau of Statistics, are exploring possibilities for using *Bangladesh: Threshold 21* in their ongoing responsibilities. Participants in the *Bangladesh: Threshold 21* training program decided, on their own initiative, to form a Users' Group to have regular meetings to discuss issues related to *Bangladesh: Threshold 21*. UNICEF-Dhaka will host such meetings and provide internet communication for the User's Group with Millennium Institute to facilitate support.

The Millennium Institute has signed an agreement with the Institute for Scientific and Technical Information of China for applications of Threshold 21 on national and provincial levels of China. The Institute is also in negotiations with other institutions concerning applications in several other countries. The Millennium Institute has developed an international Advisory Group to assist in evaluating Threshold 21 and to suggest priorities for improvement.

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