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METHODS AND EXAMPLES OF MODEL VALIDATION
- AN ANNOTATED BIBLIOGRAPHY

J. Gruhl and N. Gruhl

MIT Energy Laboratory Working Paper MIT-EL 78-022WP

July 1978

P R E L I M I N A R Y

to be annotated

Additions, Corrections,
and Annotations Would
Be Appreciated

Methods and Examples of Model Validation
- An Annotated Bibliography

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MIT-EL 78-022 WP

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July 1978

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INTRODUCTION

The complexity of computerized models has advanced to the point where human understanding is of little use as a validation tool. There are, however, a great number of other available validation tools, and this bibliography was originally collected for internal use to assemble a list of these other types of validation techniques as they have been reported in the literature. On the basis of this collection a short summary of the available techniques was presented in (I.;Gruhl,Wood;1978). It was found, however, that it would be impossible even to briefly summarize the variety and richness of reported validation methods. This bibliography, thus, has been formalized for external use and is intended as an aid to persons interested in indepth research in this field.

The initial section, I., contains what are felt to be the most important general references. Those 121 articles should provide as much information as most researchers would need. The other nine sections contain validation examples that will probably only be important for work in those particular fields. Although cross-fertilization between various disciplines should theoretically be valuable, there is probably too much information here to be adequately digested.

Simultaneous with the development of this bibliography another somewhat similar and very excellent collection has been developed and completed elsewhere (I.;Deeter,Hoffman;1978). There were 86 of the 325 references in that annotated bibliography that it was felt should be added to this report, and they have been included. Another bibliography that was found very useful was the list of 50 references circulated informally by S. Gass. However, the majority of the 761 citations of this present report were generated with the aid of computerized literature searches. Of the bases used the two most useful were COMPENDEX, with more than 500,000 citations in energy, engineering and other fields, and SOCIAL SCISEARCH, with monograph, report, and journal citations in statistics, economics, management and other fields. On journals alone these searches covered several thousand publications.

Sponsoring the research that has, among other products, resulted in this bibliography have been 1977-1979 contracts from Northeast Utilities, New England Electric System for building and validating a model for facility siting simulations; U.S. Department of Energy for building and validating a model of fluidized bed combustion emissions; and particularly the Electric Power Research Institute for independent assessments of national energy system models.

To avoid extensive repetition in the annotations a code for the different types of validation techniques has been used, see Table 1. These validation techniques involve two steps - first some piece of the model is examined or changed - then this action is evaluated with respect

Table 1. Outline of various evaluation schemes that are referred to in the annotations

ACTIONS: EXAMINATIONS OR CHANGES

OBSERVED DATA:

- 1.1 Examinations of the observed, historical, or estimation data

OBSERVATIONS-TO-STRUCTURAL:

- 2.1 Observed data perturbation effects on structure and parameters
- 2.2 Propagation of estimation error on structure and parameters
- 2.3 Measures of fit of structure and parameters to observed data
- 2.4 Effect of correlated or irrelevant observed or estimation data on structure and parameters
- 2.5 Sensitivity analysis: quality of fit of structure and parameters to observed data for altered structure and parameters (includes ridge regression)

OBSERVATION-TO-OUTPUT:

- 3.1 Effects of correlated or irrelevant observed data on outputs

INPUT:

- 4.1 Base case or recommended input data examinations

INPUT-TO-OUTPUT:

- 5.1 Examine outputs with respect to base case input data
- 5.2 Simplify, e.g. linearize, this relationship to provide understanding
- 5.3 Simplify (e.g. linearize) structural form analytically, or group parameters to provide better understanding, elimination of small effects, grouping of equations, grouping of parallel tasks
- 5.4 Develop confidence measures on outputs by propagating input error distributions through structural error distributions

STRUCTURE:

- 6.1 Structural form and parameter examinations
- 6.2 Respecification, that is, make more sophisticated some of the structural components
- 6.3 Decompose structure physically or graphically
- 6.4 Provide new model components to check effects of assumed data or relationships

STRUCTURAL-TO-OUTPUT:

- 7.1 Examination of outputs for various structural and parametric perturbations and error distributions

OUTPUT:

- 8.1 Examination of outputs

OUTPUT-TO-INPUT:

- 9.1 Examination of optimal inputs (controls) to reach target outputs
- 9.2 Contribution analysis, percentage changes in outputs due to changes in inputs

BASES FOR COMPARISON

- A. Comparison with other empirical models
- B. Comparison with theoretical or analytical models
- C. Comparison with hand calculations or reprogrammed versions of model components
- D. Data splitting on observed data, by time or region
- E. Obtain new estimation/prediction data with time, new experiments, or in simulated environments
- F. Examination of reasonableness and accuracy, that is, comparison with understanding
- G. Examination of appropriateness and detail

to some basis for comparison. Of the 20 possible actions times 7 possible comparisons only about half of these 140 combinations make sense. In the table: Observed data are historical, or other, data used to build the model; input and output are those data associated with a particular predictive use of the completed model; and parameters are those constants or specified functions that are intended to remain unchanged for different model applications. Utilizing the code in Table 1, for example, using 6.1.B would mean a direct examination of structural form or parameters of the model with respect to other similar theoretical or analytical models.

Additions, corrections, and annotations for this bibliography would be appreciated and should be sent to the authors.

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III. Validation of Energy and Electric Power Models

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