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THE OBJECTIVES AND REQUIREMENTS OF MODEL MANAGEMENT * +

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ABSTRACT

Model management is a technology evolving by necessity, pushed by the attempts to deal with increasingly complex systems and the perceived inadequacies of past efforts. This rapid evolution of Model Management Systems (MMS) has created different perspectives of the role of the MMS: one arising in the database and decision support systems research community stressing the user's interaction with a model data bank and the other view from the modeling community emphasizing the model development functions. These two perspectives are clarified and reconciled by relating each to the model life cycle, which leads to a more comprehensive statement of MMS requirements.

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The Objectives and Requirements of Model Management

Rapid advances in computing technology have encouraged increasingly more ambitious simulation studies. The size and complexity of the modeling efforts, involving managers, analysts, and programmers often working in separate locations, forces the application of computers to the management of the modeling activities. Model management should begin in the earliest phases of the model life cycle and provide support throughout, although the requirements and the users served vary as the modeling project matures. Examples of components of a model management system (MMS) can be identified, but an integrated, comprehensive tool set, truly representative of a MMS, remains as a future goal.

1. The Context for Model Management

Understanding the objectives of model management must begin with a clear perception of the phases in the development, use, and extended application of a model, which can easily represent a multi-million dollar investment and a time span of five years or more. Figure 1 is an illustration of the model life cycle that portrays a chronology of phases (shown by oval symbols) that, although arbitrary, prove to be generally descriptive of *large* modeling efforts. We digress here only slightly to emphasize the focus on "large" efforts; for, much like the software development task, small models require little in the way of good techniques or supporting tools.

The processes shown by dashed arrows in Fig. 1 should in no way be interpreted as sequential. Modeling is iterative in nature, and accomplishment of the modeling task forces "looping" among the phases. A modeling project is initiated in the third phase of the life cycle. However, it is the responsibility of the MMS to verify the formulated problem and assess the feasibility of modeling by explicit referral to the earlier processes.

While Fig. 1 is considered generically descriptive of model-based problem solving, we restrict our attention to simulation models in the following paragraphs. A broader treatment, exploring the relationships among the phases in greater detail can be found in (Balci and Nance 1983) and (Balci 1983).

1.1 The Model Life Cycle Chronology

The problem definition phases represent the initial struggles with misperceptions and biased reactions, the delineation of cause and effect relationships, the consideration and reconsideration of the problem statements in concert with potential problem-solving approaches, and the deliberation or negotiation of the extent of the simulation study. The difficulties in problem formulation can surface as a mixture of technical, political, and personal factors hopelessly interwoven (see Balci and Nance 1983). While a MMS can assist with all factors, the technical sources represent the primary concern.

The model development phases form the core needs for model management and the consequent *raison d'etre* for model management systems. Beginning with the establishment of system boundaries and the definition of study objectives, the development includes conceptualization and representation, verifica-

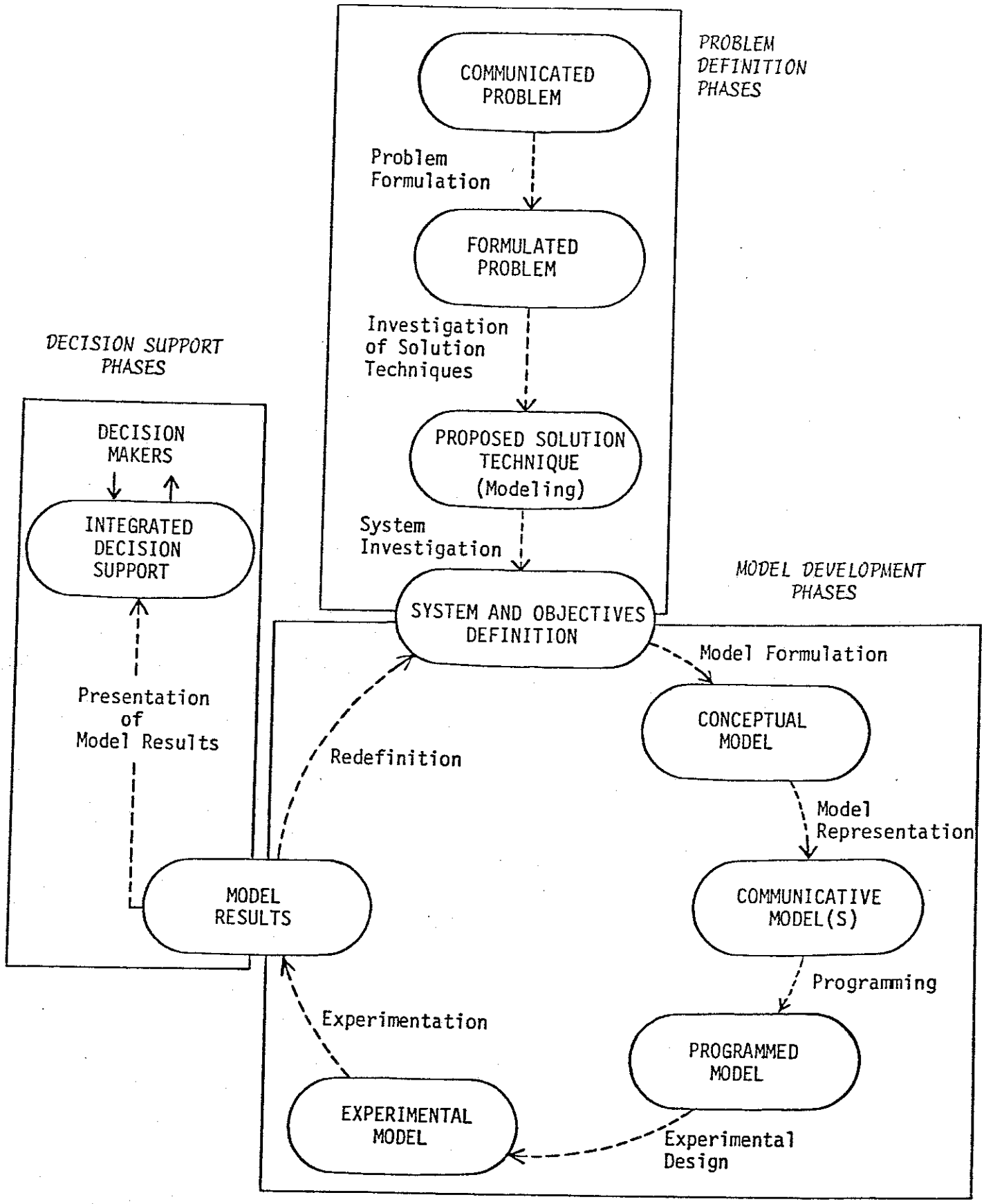

Figure 1. Phases in the Chronological Periods of the Model Life Cycle.

tion and modification, programming and documentation, testing and validation. Concluding with validation and the experimentation leading to results required for implementation, model development comprises the creative activities most frequently associated with model-oriented problem solving.

The decision support phases are the often ignored post-results periods during which the results, and model itself, are used or "conditioned" for continuing use. Attempts to expand or enhance the model in response to system changes or newly defined objectives are included here. Note that extensions of the model to changes in the original study (system or objectives) or to the adaptation of the model to a different problem situation could be pictured as introducing a new life cycle or continuing an older one, depending on the extent of the differences.

1.2 The Role of Model Management

By partitioning the model life cycle phases into three chronological categories, we can explain two widely different perspectives of model management systems revealed in the current literature. One view, that advanced predominantly by researchers in management information systems (MIS) and decision support systems (DSS), holds that a MMS is analogous to a database management system, with models replacing data as the essential resource (Will 1975; Sprague and Watson 1975; Sprague 1976). Taking this view the *model bank* becomes a part of the MIS (Will 1975, p. 468). Consequently, the "model management system is a software system that facilitates user access to models" (Blanning 1982).

The second perspective is taken by those working in the modeling community. This group includes researchers in computer simulation and in mathematical programming. The modeling community has focused on the techniques of model development (Nance 1977; Oren and Zeigler 1979; Zeigler 1980; Nance, et.al. 1981) total model development systems (Holbaek-Hanssen, et.al. 1977; Mathewson 1978; Bisschop and Meeraus 1982; Mathewson 1983; Meeraus 1983), and computer-assisted model analysis (Kurator and O'Neill 1980; Greenberg and Maybee 1981; Greenberg, et.al. 1981; Nance 1981; Overstreet 1982; Greenberg 1983).

Differences in the two perspectives can be explained by reviewing Fig. 1. The MIS research community, even when expressing a holistic definition of the MMS (Elam 1980), has dwelled on the decision support phases of the model life cycle; i.e., the effective organization and use of models within the framework of decision support. This view reflects the concern for the decision maker as end user having "a primary impact on problem definition and eventual success of the DSS" (Elam, et.al. 1980, p. 100).

The modeling community has focused on the model development phases shown in Fig. 1, principally addressing the modeler or analyst as the user. Both views are correct, but each can profit from mutual recognition of the other. Further, both need to be concerned for the problem definition phases, which seem to receive comparatively little attention; e.g., see (Wooley and Pidd 1981; Balci and Nance 1983).

2. Requirements of a Model Management System

Expansion of the tabular presentation used in (Nance, et.al. 1981) widens the perspective beyond the model development phases and draws a clear correspondence between model management objectives and MMS requirements. The users of a MMS, identified in the above reference as:

(1) The *organization manager*, who supervises

(2) several *project managers*, who manage project teams made up of

(3) *analysts*, primarily responsible for the model definition and specification, the experimental design, the data definition and organization, and the presentation and interpretation of model results, who are supported by

(4) *simulation software development managers*. (The chief programmer position to use the terminology of (Mills 1971), who conform the data definition and organization to the logical and physical requirements of a data base management system and computer system configuration, and instruct

(5) *programmers*, who develop the programmed model representation in an executable language.

To these users, the last four of which are designated collectively as the "Project Group," we add

(6) *client manager(s)*, who request or "fund" the modeling projects and who potentially employ the model and results for decision support. This group includes both the "decision maker" and the "model user" described in (Elam, et.al. 1980).

The six user groups represent differing levels of responsibility within the phases of problem definition, model development, and decision support. Although levels might be combined for a specific project, this degree of detail is helpful in the explanation of MMS requirements.

2.1 Problem Definition Requirements

The model management objectives in the problem definition phases include accurate problem formulation consistent with study objectives, consideration of alternative problem-solving approaches, and the preparation of the requisite communication channels between the modeling organization and the client manager(s), see Table 1. An overriding concern is the credibility of the model and results; thus, technical, organizational ("political"), and personal factors cannot be ignored (Balci and Nance 1983).

2.2 Model Development Requirements

The objectives in the model development phases pertain to enhancement of the expression of modeling concepts, improvement in the efficiency and effectiveness of the study, assistance in achieving correctness through verification and validation procedures, and expansion of the model applicability and utility (Nance, et.al. 1981). Table 2 shows the derivation of model development requirements of the MMS. Two requirements in Table 2 deserve some elaboration:

(1) Tools that assist in assuring model correctness should be employed early in the model development phases. Diagnostics should be applied *before* a programmed representation so as to guide program design and test.

(2) Model documentation must be inseparable from model specification, stratified in its description of model components (reflecting the principle of information hiding (Parnas 1971,1972)), and descriptive of the modeling activity as well as the product.

A broader treatment of model development requirements can be found in (Balci 1983).

OBJECTIVES OF MODEL MANAGEMENT (Problem Definition)	REQUIREMENTS OF A M.M.S. (Problem Definition)	USER
1. Given a communicated problem from a Client Manager, develop a formulated problem.	1. (a) Provide communication between Client Manager, Organization Manager, and Project Manager.	Client Mgr. Organization Mgr. Project Mgr.
	(b) Facilitate full documentation of the formulated problem.	Organization Mgr. Project Mgr. Analyst
	(c) Provide computerized assistance for the verification of the formulated problem.	Client Mgr. Project Mgr. Analyst
	(d) Furnish data base support for analysis of data in assigning cause and effect relationships.	Project Mgr. Analyst
	(e) Offer computerized assistance for effective presentation of findings and proposals.	Project Mgr. Analyst
2. Given a formulated problem, assist in the investigation of alternative problem-solving techniques leading to a proposed model-based approach.	2. (a) Furnish data base support for investigating solution techniques.	Project Mgr. Analyst
	(b) Provide premodels data base support for assessing the feasibility of model-based approach chosen.	Project Mgr. Analyst
3. Investigate the system characteristics, define the system boundaries, and compose the study objectives.	3. (a) Furnish data base support for access to complete documentation on the definition of system and study objectives.	Project Mgr. Analyst
	(b) Determine the project personnel, resources, and schedule.	Project Mgr.
	(c) Offer graphics and text formatting software for presentation purposes.	Project Mgr. Analyst
	(d) Provide communications between Analyst, Project Manager, and Client Manager.	Client Mgr. Project Mgr. Analyst

Table 1. Problem Definition Requirements of a Model Management System

OBJECTIVES OF MODEL MANAGEMENT (Model Development)	REQUIREMENTS OF A M.M.S. (Model Development)	USER
1. Given a problem that requires a model or models to reach a solution, produce an effective model with an efficient effort that concludes in a reasonable time.	1. (a) Provide access to previously developed models and submodels, data, experimental designs, model results, and implementation results.	Project Group
	(b) Furnish tools for model development that: (i) speed the realization of a communicative model, (ii) assist in assuring model correctness, (iii) coordinate the experimental design from the outset, (iv) relieve the modeler of programming nuances in the production of the programmed model, and (v) enable model documentation to be an integral product of the development effort.	Analyst
	(c) Provide for the scheduling of milestones monitoring of progress, and control of costs in the production of a model.	Organization Mgr. Project Mgr.
	(d) Assist in the realization of a model representation in an executable language.	Programmer
2. Permit the use of models to range from long-term policy formulation and strategic planning to short-term (quasi-real-time) decision making. (To use Kiviat's terminology: (Kiviat 1977) model directed management.)	2. (a) Enable direct interaction of managers with models.	Organization Mgr.
	(b) Promote the understanding of models at different levels--high level for "top" managers, intermediate level for analysts, and detailed level for analysts and programmers.	Project Group
	(c) Promote a progressive learning of model details guided by the manager/user.	Project Group
3. Enable information to be obtained from completed, in-progress, or planned modeling efforts to meet: (1) legal or jurisdictional requirements, or (2) prediction/ planning needs.	3. (a) Organization of a database for prior modeling projects that can be interrogated by status, resources used, and other characteristics related to model description and prediction/planning.	Project Group
	(b) Representation of submodels, models, experimental design, experimental outcomes, and model modifications.	Project Group

Table 2. Model Development Requirements of a Model Management System (Nance et.al. 1981)

2.3 Decision Support Requirements

The objectives in the decision support phases center on the properties that make a system useable over an extended period of time -- extensibility, user-friendliness, and flexibility. To these three is added the objective of supporting the incorporation of adaptivity or knowledge in the decision support functions. The opinions and perceptions expressed by several authors are reflected in the descriptions used in Table 3; namely, (Will 1975), (Elam, et.al. 1980), (Elam 1980), and (Sprague 1976).

3. Summary

Based on the model life cycle chronology, the divergence of views of "model management" found in the literature is explained. The database management and decision support research communities have focused primarily on the decision support phases; while the mathematical programming and simulation research communities have dwelled on the model development phases. Both views are needed, and both must be coupled with objectives arising from the problem definition phases in order to develop a comprehensive statement of MMS requirements.

OBJECTIVES OF MODEL MANAGEMENT (Decision Support)	REQUIREMENTS OF A M.M.S. (Decision Support)	USER
1. Facilitate the integration of newly developed models into the decision support system of the client manager(s).	1. (a) Furnish structure, documentation, and format assistance in the addition of models, data, experimental frames (Zeigler 1976, p. 30) results, to the decision support system of the client manager(s).	Organization Mgr. Project Mgr.
	(b) Monitor concurrence with standards for additions to DSS.	Project Mgr.
2. Offer easy access to models, data, experimental frames, results for a variety of client managers, who need not have programming (computing) knowledge.	2. (a) Provide access that is non-procedural yet does not prove burdensome to the technically knowledgeable user.	Client Mgr(s).
	(b) Enable a user to tailor the interface and access in prescribed ways.	Client Mgr(s).
	(c) Offer efficient access for varying information needs that can be accomplished through varying database organizations.	Client Mgr(s).
3. Provide flexibility in the additions, deletions, and modifications of resources needed for decision support.	3. Maintain modularity and independence so that changes in data, models, experimental frames, and results or modifications to the host hardware and software do not require major MMS redesign.	All
4. Enable knowledge-based support of decision making.	4. Permit the utilization of artificial intelligence techniques in knowledge representation so that a knowledge base linking the various aspects of simulation experimentation (data, models, experimental frames, results) can be developed.	Client Mgr(s). Project Group Programmer

Table 3. Decision Support Requirements of a Model Management System

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