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Special recognition is extended to Professor Thomas R. Prince for direction and support throughout this study and to my wife, Anita, who typed and endured.

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I. MEASUREMENT PROBLEMS IN AN ADVANCED MANAGEMENT ENVIRONMENT

Recent developments in management science, both in the academic and applied spheres, have produced a management environment with new dimensions in methodology as well as technical capability. Many of these developments have been mutually enabling and reinforcing such that their combined impact has been more significant than the sum of the individual contributions.

Advances in operations research technology have led to numerous applications of optimizing models to significant management decision areas. Theoretical work in mathematical programming, queueing theory, statistical sampling and multivariant regression and discriminant analysis has provided the basis for feasible and profitable solutions to specific problems in inventory control, credit screening, resource assignment and optimum input-output mix determination.

The realization of these operations research potentials requires substantial computational and data base resources. While computer facilities and computer based operating systems are not prerequisite to this realization, the increasing availability of such resources has greatly facilitated operations research efforts and has spurred the development of more sophisticated techniques which previously would not have been feasible.

With the development of advanced hardware and software capabilities, computer based operating systems have become more integrated and systems oriented. The design and implementation of multi-purpose data bases and the coding structures required to maintain them have given a new analytical emphasis to the interrelationships among various organizational units, objectives and decision processes. To an increasing degree significant payoffs have been realized not from a "deepening" of operations research efforts through the development of more precise models for specific decision processes, but rather from a broadening of the systems context or perspective within which such work is conducted.

This change in emphasis, particularly apparent in advanced management of large-scale, complex systems, has given rise to a number of conceptual frameworks and quasi disciplines. Systems analysis, management by systems, planning-programming-budgeting and other similar developments reflect this movement to systems oriented management. While the concepts underlying these developments are not new, they have taken on new meaning in a management environment supported by advanced operations research and computer technology capabilities.

It is a truism that subsystem performance and the interaction among subsystems should effectively contribute to total system objectives. However, the development of analytical models capable of evaluating the total impact of subsystem decision processes and planning alternatives is a relatively recent phenomenon. Furthermore, the data base and data processing resources required to implement such models are only beginning to become available.

The size and data handling efficiency of computer systems has increased by a factor of ten while the cost per unit capacity has decreased by a factor of ten during the past decade.[1] This increase in the power and availability of computer systems has led to a great expansion in business applications. However, in large measure, these applications have been confined to the automation of existing clerical functions or, on a more advanced level, to the implementation of programmed decision rules in specific operating systems or subsystems. Relatively little progress has been made in applying these resources to broader problems in total system management.

This course of evolution in systems development and direction has not resulted from an unawareness of broader systems problems nor from any discounting of the significance of these problems. But rather, the application of limited systems research and development resources to the hierarchy of possible systems activities beginning with the most immediately realizable and largest payoff areas represents a rational approach to systems planning over time. In general, it would be expected that this approach would lead to intense efforts directed at specific problem areas or decision processes which are perceived to be most crucial in realizing organizational objectives as well as possibly less significant systems functions which may be particularly amenable to analysis and systemization. This expectation is evidenced by the proliferation of sophisticated inventory control and production scheduling systems on the one hand and packaged accounts receivable and payroll systems on the other.

As a particular organization continues to develop specific high payoff systems applications over time, the marginal contribution of more intensive sophistication in these specific areas may be expected to diminish while the significance of interactions among these subsystems becomes more acute. At the same time the cumulative effect of these diverse systems applications and experiences establishes a higher level of systems sophistication in terms of organizational resources, systems development capabilities and managerial orientation. Over time, these factors result in an increasing need for a broader systems perspective encompassing existing systems applications and capable of structuring or relating these subsystems to higher systems objectives. In this context, a coherent methodology or structured process of analysis is required to bring existing systems resources to bear upon total system objectives and relationships.

Two major areas must be developed before significant progress in this respect can be expected. First, the methodology of information systems analysis, involving identification and structuring of management decision processes and operational definition of the associated information requirements, must be investigated in the context of ongoing business organizations.

Second, the rapidly expanding resources of operations research and computer technologies must be marshalled to incorporate these information requirements into the continuing information systems activities of the organization.

The development of these areas essentially requires (1) a methodology for constructing an information systems model of an organization which can be used to identify and operationally define the information requirements of major decision processes, and (2) a measurement system capable of satisfying these information requirements through operations on existing or feasibly obtainable data. Both the systems model and the measurement system must be highly decision oriented and capable of tracing the impact of decision variables through large segments of the total organization possibly involving complex interactions and interdependencies among various related subsystems or decision processes.

Traditional internal accounting systems, e.g., responsibility and profitability accounting, represent one possible approach to the development of a systems model and a measurement system. The model commonly consists of a hierarchy of classifications, e.g., responsibility centers, profit centers, cost centers, defined in terms of organizational structure, product lines or functional operations. These classifications form the basis for a coding structure which keys operating data, generally dollar values, to the specific center or centers to which they are related.

Periodically, the values posted to these classifications are summarized and interpreted as measurements to be compared with budgets and standards or enter into new plans and decisions all of which must be framed, explicitly or implicitly, in the same classification scheme.

While this coding structure model is commonly multidimensional, each dimension or set of classifications defines a unique distribution of relevant data among independent categories. Accordingly, the measures of performance or decision information inputs derived from such a system must be defined in terms of some combination of these independent categories. However, in a total systems context, involving complex interactions among subsystems and decision processes, many significant information requirements cannot be specified in terms of predefined, independent elements. The impact of a given decision variable upon total system performance may depend upon its interaction with various other decision processes perhaps controlled by separate decision makers each with somewhat different objectives. The exact nature of the interaction effects cannot be specified in advance since they depend conditionally upon numerous system variables.

This problem cannot be overcome by adding a dimension to the coding structure or refining the definition of categories. The traditional systems model based upon a hierarchy of classifications is simply inappropriate for certain measurement requirements. A new systems model and measurement system capable of tracing the impact of decision variables through large segments of the total organization is required.

These problems and objectives compel a reexamination of existing systems relationships and systems development activities at a higher, more integrative systems level. The information systems analysis process, variously articulated in the management science and industrial engineering literature, is addressed to this purpose. If the principles of this methodology can be operationalized in relation to the needs outlined above as well as the unique resources and orientation of the advanced management environment, significant contributions could be realized.

The objectives of this study, then, are to (1) identify the extensions to the information systems analysis process required to meaningfully address significant measurement problems in an advanced management environment and (2) develop a methodological base for operationalizing these extensions. As outlined below, these objectives are pursued first, through a conceptual examination of the system model and measurement system requirements of the high level information system analysis process and second, through an extended field study exploring the characteristics and potential contribution of the proposed modeling and simulation methodology.

The information systems analysis process is examined in Chapter II with particular emphasis on the dimensions or aspects of the process which require extension or elaboration in order to meaningfully address the problems and objectives set forth above. While the information systems literature is highly diverse and generally directed to specific application areas, Chapter II focuses upon the underlying framework common to much of the literature rather than specific studies. This macro framework provides the systems analysis structure within which specific methodological questions can be meaningfully related to the objectives and requirements of the analysis process. Specific analytic techniques, which may be well established at a micro application oriented level, take on new meaning and significance when related to broader systems inquiries through such a framework. This examination of the (1) organization review, (2) systems analysis, (3) measurement and evaluation and (4) implementation phases of the information systems analysis process reveals an underlying need for an operational system model and corollary measurement system to support meaningful analysis in the context of an advanced management environment. The general characteristics of these requirements are further analyzed at a conceptual level.

The potential contribution of computer-based modeling and simulation as an operational basis for the required system model and measurement system within the information systems analysis process is examined in Chapter III. Following a brief review of the state of the art in simulation based studies, the concept and unique features of computer-based modeling and simulation are evaluated in relation to the requirements of the analysis process. This evaluation is then extended to consider the systems development and organizational resources required to support simulation based analysis.

The operational implications of incorporating computer-based modeling and simulation within the information systems analysis process are analyzed in Chapter IV. The role and interaction of modeling activities in relation to relevant aspects of the analysis process are examined in some detail with particular emphasis on the unique requirements and resources of the advanced management environment. In this context, computer-based modeling is presented as a heuristic, iterative process evolving with the ongoing system through time.

The conceptual framework developed in the first four chapters is represented to be application oriented in the sense of meaningfully addressing significant systems problems with respect to existing ongoing organizations. While the scope and magnitude of the proposed methodology in relation to state of the art applications effectively preclude meaningful sampling or survey efforts to establish the viability of the approach, the necessity for some empirical evidence is apparent. Accordingly, an extended field study was undertaken in which a high level analysis through computer modeling and simulation was initiated in a significant ongoing advanced management context. The objective of the field study was to explore and evaluate major dimensions of the proposed methodology including significant potentials, requirements, and limitations in a real world application.

The environmental and organizational setting underlying the field study application is introduced in Chapter V. This introduction is structured to parallel the requirements of the analysis process and provide a basis for exploring the formal modeling activities. A number of significant systems problems and management information requirements are identified in this context and incorporated in the analysis process.

Drawing upon the field study experience, significant dimensions of the analysis process are discussed in Chapter VI. The nature of data requirements, data acquisition systems, processing and analysis requirements, computer-based modeling activities and elements of validation testing are examined in this context with reference to empirical observations associated with the field study. The technical appendix to Chapter VI presents summary, skeleton documentation of the SIMSCRIPT based system model developed in the course of the field study.

Broad ranging potential application of the field study computer-based system model as a measurement system is examined in Chapter VII in the context of further implications and extensions. Broader questions including behavioral implications, expanding the concept of modeling, and quasi optimization techniques in simulation based analysis are also discussed in Chapter VII as significant areas for further research with some tentative indication of the potential direction and contribution of these efforts.

II. A BASIC FRAMEWORK FOR APPROACHING SELECTED MEASUREMENT PROBLEMS

Information systems analysis and design is a broad, dynamic area which draws from numerous disciplines and technologies. The various aspects or dimensions of the information systems process are highly interdependent, yet, being based in different disciplines and having attained different levels of development, they are seldom fully compatible conceptually or in application. As a result, it is often difficult to appraise the contribution of specific techniques and developments without evaluating their relationship to other aspects of the process which may be framed in a different conceptual scheme and set forth in a different vocabulary. In order to avoid this problem and establish a frame of reference both to delimit and to evaluate the contribution of this work, a brief review of the information systems process may be useful.

While any breakdown of such a complex, highly interdependent area is quite arbitrary and runs the risk of blindering the analyst with a rigid conceptual framework, the information systems process will be discussed in four parts below. This breakdown is not intended to suggest any priorities or any real possibilities of separating the process into independent parts; it is merely a framework for discussion. These qualifications having been made, the information systems process will be reviewed in terms of (1) organizational review, (2) systems analysis, (3) measurement and evaluation, and (4) implementation.

ORGANIZATION REVIEW

Organizational review examines the interface between corporate objectives, resources and constraints with the organization's environment including relevant markets, legal restrictions, social requirements etc. This interface together with a value system (explicit or implicit) which orders the desirability or value of alternative futures, comprises the underlying basis for corporate strategic planning or resource allocation decisions. This interface also implies a set of system requirements and operating decisions which must be executed (explicitly or implicitly) to optimize resource utilization within the strategic planning framework.

Little tangible progress has been made in the derivation of these required bases for strategic planning and operating management models. The organization-environment interface represents the interaction of a complex, open system with a multitude of interrelated variables and parameters most of which are unstable, cannot be reliably predicted or controlled and often cannot be measured or even identified. While the study of closed systems has progressed through application of the scientific method and mathematics, the understanding of nontrivial open systems is spotty at best and comprehensive, analytical work with large-scale, complex open systems is largely beyond the state of the art.

Specification of operative value systems with any degree of validity beyond highly restrictive, hypothetical models has also progressed slowly. The underlying problem in this area permeates much of the work in psychology and sociology. The necessary concepts, relationships and entities are not sufficiently refined in theory or application, to establish operational systems of definition and measurement required to support meaningful scientific progress. This lack of operationalism undoubtedly arises from the extreme degree of complexity encountered in social systems, which is generally beyond the grasp of existing formal analysis techniques.

As a result of these problems and weaknesses, the organizational review process necessarily involves the use of highly simplified surrogates to represent complex phenomena and far ranging assumptions, often with little empirical basis, to delimit and redefine the analysis to manageable proportions and tractable formulations. While such an approach may not be preferred, it may be necessary and often useful. But the approach is frail and will lead to different conclusions with varying degrees of validity as the underlying assumptions change over time, with the situation or with the specific analyst.

Since the organizational review process forms the basis for subsequent analysis, there is a danger that elaborately precise analytic models may be based upon an incomplete, questionable and changing structure of assumptions and simplifications. Indeed, fascination with specific models in the strategic planning or operations management areas may lead the analyst to look for, and perhaps find, some interpretation of the organization-environment interface and some value system which will support or logically imply his preconceived conclusions. Furthermore, once an elaborate model is established in this fashion, the eloquence of the model becomes an effective (even if invalid) argument for the required interpretation of the organizational review. This kind of reverse reasoning often leads to irrelevant conclusions, no matter how precise and well formulated they may be, and to a conceptual rigidity which may impair development of the new perspectives and interpretations required to form a basis for more meaningful analysis. This problem will be revisited in subsequent sections of this discussion.

The theoretical and analytic work required in the organizational review area is highly significant and has implications for important research efforts far beyond the information systems area. The substance of possible solutions to these requirements lies outside the scope of this paper; however, the relationship of operational information systems models and measurement systems to the organizational review process is important and should not be ignored. An awareness of the assumptions and conceptual foundation underlying subsequent analytic work in the systems analysis and design process is necessary to produce meaningful results. Furthermore, the state of the art in the organization review area suggests that it is essential for the methodology of systems modeling and analysis to be broadly based and flexible enough to incorporate new assumptions and conceptual frameworks as they develop over time.

SYSTEM ANALYSIS

The systems analysis process involves an analytic examination of the decision processes identified in the organization review. The overall objective of this analysis is the determination and structuring of the input and output requirements of these decisions. The required decision outputs, e.g., resource allocations, product pricing, competitive strategies, operating policies, etc., are primarily derived in the organization review and comprise the conceptual link between that phase of the information systems process and the formal systems analysis. The decision inputs or information requirements in turn provide the basis for the subsequent phases of systems design and implementation.

The analysis and structuring of decision processes requires some form of systems model. The specific models used may be explicit and formal or unstructured and intuitive. Highly developed operations research models are often applied in such areas as inventory control, production scheduling and distribution while more intuitive, judgement based models may be employed in evaluating corporate policies and competitive strategies.

At the present state of the art, a number of distinct models representing various methodologies with varying degrees of sophistication may be applied to specific decision areas, operating systems or organizational units. The information requirements defined by these decision models are then structured into one or more integrated frameworks based upon common time frames, data requirements, information channels, organization hierarchy etc. The resulting specification of information requirements seldom achieves a total system orientation. Rather, it represents a systematic merging of selected information requirements derived from a number of independent or only partially integrated decision models.

The systems analysis, as a logical extension of the organization review, seeks to define the decision information inputs required to optimize or effectively pursue total system objectives. In this context, a major function of the analysis process is to build a formal understanding of the total system and the operational relationship of system components to the realization of total system objectives. Only in the special case where all subsystems are independent and their impact upon total objectives is in some sense additive or functionally separable, can the merging of independent decision models effectively represent the total system. Only when the interactions and interdependents among decision models can be ignored or functionally determined a priori, can the simple sum of the parts meaningfully represent the whole. These conditions are seldom fulfilled in significant, real world systems.

In the absence of a meaningful total systems model, it is difficult to evaluate the appropriateness and significance of a specific decision model beyond its immediate local context. As a result the criteria for choosing or developing a decision model are often drawn primarily if not exclusively from the specific problem area or local subsystem involved. The implications of broader and perhaps competing criteria arising from other aspects of the total system are often overlooked or assumed away. This danger is particularly strong when an operations research group, more familiar with solution techniques than the decision process itself, is responsible for a specific decision model, but has neither the authority nor the competence to examine total system implications. Immediate, local payoffs may justify implementation of the model, but significant suboptimalities or counter productive side effects may develop over time. Furthermore, the appeal of precise operations research formulations may distort the analyst's overall perception of the problem and introduce an undesirable element of rigidity into his analysis.

Clearly, the systems analysis phase of the information systems process requires a broad systems orientation and an ability to integrate diverse analytic methodologies and techniques. At this stage of the process, an awareness of total system relationships and the interactions among subsystems and major decision areas is more important than elaborate optimization models for specific decision processes. The development of an operational methodology for realizing these objectives is discussed in Chapter III.

MEASUREMENT AND EVALUATION

The decision information requirements identified and structured in the systems analysis phase must be linked to data and information sources through a measurement system. In this context, a measurement system essentially consists of a set of defined operations on existing or feasibly obtainable data to produce required decision information inputs. The set of defined operations may include operations research models, data storage and retrieval systems, classification structures, statistical computations etc. These operations may be performed through a series of computer programs, clerical activities or qualitative judgement processes.

The measurement system must be capable of operationalizing the information requirements defined in the systems analysis. If the analysis process achieves a meaningful systems orientation, relating specific decision areas to total system objectives, the resulting information requirements will involve measures which reflect the impact of decision variables upon total system performance. Except in the special case where the relevant decision processes are independent or their impact on total system performance is functionally separable *a priori*, the measurement system must be capable of tracing the impact of specific, local decision variables through perhaps several levels of interactions with other decision processes, subsystems etc. in order to evaluate the resultant effect on the total system.

At the present state of the art, just as the systems analysis is commonly fragmented into a series of quasi independent decision models, the related measurement processes fail to recognize the total system implications of local decision variables and alternatives. Indeed, when the analysis process is undertaken primarily for the realization of direct payoffs from the application of specific operations research models, the scope of the analysis and of the resulting information and measurement requirements is typically quite restricted. While these applications may be useful in a local context, they seldom achieve the total system orientation required to effectively integrate diverse decision areas in the pursuit of total system objectives.

The range of measurement requirements is quite broad. It may be required to evaluate the impact of policy and resource constraints, strategic and operational planning alternatives, control systems, decisions rules and specific decision variables as well as the information and physical linkages among organizational units, functional subsystems, decision centers etc. In general, these information and measurement requirements cannot be fully specified in the systems analysis. New requirements may be generated through changing perspectives in the organization review or dynamic interactions within the system. Consequently, the measurement system must be broadly based and flexible enough to incorporate new or changing requirements as they may develop over time. A measurement system based upon rigid operations research formulations, restrictive coding structures etc. may be significantly limited in this respect.

Again, at this stage of the process, a capacity to deal with total system relationships, evaluate interactions among decision processes and accommodate a broad range of measurement requirements is more important than absolute precision and elaborate detail in specific areas. An approach for achieving these objectives as an extension of the systems analysis process is the subject of Chapters IV and V.

The measurement system must define requirements for data base content and structure. One danger in a piecemeal approach to the information systems process is that each successive step or addition to the system may be distorted to use existing data and data base structures. Ideally, the requirements of the measurement system should determine the content and structure of the data base; unfortunately, in practice this causality may be reversed. The definition of the data requirements is discussed in the context of developing the measurement system. Data base structure and implementation involves technical questions of computer hardware and software characteristics or clerical organizations which lie outside the scope of this discussion. These questions will be dealt with only by example in the field study presented in Chapter VI.

IMPLEMENTATION

The implementation phase of the information systems process consists of the detailed system design activities required to operationalize the decision models, measurement system and data base requirements defined in the preceding phases of the process. The information flows linking data sources with information requirements through the measurement system must be specified in detail with respect to time frame, transmission channel, media and format, organizational responsibility and perhaps priority, limited accessibility etc. The determination of these factors involves an evaluation of specific organizational characteristics including computer and data processing resources. This general area has received considerable attention in literature. Indeed, many references to "information systems" are addressed specifically to topics in implementation rather than the the more conceptual areas emphasized in the preceding sections. The substance of these topics lies outside the scope of this paper.

One aspect of implementation which only recently has received the attention it warrants is the management education, training and experience required to effectively realize information systems objectives. The total system orientation and awareness of relationships and interactions among subsystems and decision processes emphasized in the preceding sections, utimately must be operationalized through management personnel. This objective requires a high degree of commitment, involvement and conceptual understanding among top and upper middle management throughout the information systems process.

Indeed, an important function of the systems model and measurement system should be to provide management with an integrated conceptual framework for structuring their experience and educating their judgement with respect to systems relationships. This framework should serve as a common basis for formulating, articulating and evaluating various management alternatives and perceived problems. In this sense, the systems model and measurement system comprise an analytic, systems oriented language or symbolic representation which facilitates essential communication of ideas, correspondence of objectives and coordination of efforts among subsystems, decision centers and various management groups. Accordingly, an important criterion for evaluating the methodologies and techniques employed in the information systems process is the extent to which they contribute to effective management involvement, understanding and communication. This criterion will be considered in evaluating the approach to systems modeling and measurement set forth in succeeding chapters.

An extension of this aspect of implementation, which lies at the fringe of current research, is concerned with the continuing development and evolution of the information system as the organization grows and changes over time. Growth is seldom merely a matter of size. As an organization grows it may change significantly in terms of product offerings, competitive strategies, organizational structure, management requirements etc. Even a stagnant organization must adapt to change brought about by product life cycles, new competition, changing market characteristics etc.

In order to adapt to change effectively, management must be able to identify and evaluate the total system implications of new requirements and alternatives as they develop over time. This objective demands a total system awareness which extends beyond current decision models, information flows and operating systems. In this context, management must be prepared to question the very objectives and assumptions upon which the existing information system is based. These activities constitute a major part of the strategic planning function which may be differentiated from the "housekeeping"[1] or operating information system in an advanced application.

The full implications of the strategic planning function will not be explored in this paper; however, this function implies certain requirements for the systems model and measurement system which cannot be ignored. If the systems model is to grow with the organization and provide a meaningful frame of reference as the organization changes over time, it must derive from a broad, dynamic methodological base which can be expanded to incorporate new assumptions, requirements and technologies. A rigid, narrowly conceived systems model may not only fail to serve the needs of a strategic planning function, but moreover, may actively inhibit the broad, imaginative systems rethinking required to achieve strategic planning objectives.

Similarly, the measurement system must be capable of operationalizing information requirements beyond those specified by existing operating decisions. The strategic planning function may require measures reflecting the impact of fundamental changes in the organization's objectives, resources and constraints upon which existing decision processes, operating systems and information requirements are based. If the measurement system is rigidly tied to existing information flows and operating systems, it cannot fulfill these requirements. In order to serve the strategic planning function, the measurement system must grow and evolve with the system model as the organization and its environment change over time.

SUMMARY

While the preceding sections have reviewed the information systems process in four parts or phases, it is important to recognize the essential continuity and interdependence of the various objectives, requirements and activities involved. Information systems analysis is necessarily an iterative process with numerous feedbacks among its conceptual phases or stages. As the systems analysis is developed, the analyst may gain new insights and perspectives which modify his conclusions from the organization review or suggest whole new avenues of investigation. Design of the measurement system may reveal conceptual inconsistencies in the systems model or additional loose ends in the organization-environment interface. Finally, problems encountered in implementation may cause recycling and rethinking of previous activities possibly resulting in significant modifications and additional iterations.

Again, the importance of maintaining a broad system orientation and resisting the tendency to solidify premature conclusions in elaborate detail must be stressed. The methodological base for systems modeling and measurement should support these objectives by facilitating the rethinking of systems relationships in a flexible mode which can expand with the analysis and freely accommodate changing assumptions and perspectives.

The information systems process is a general methodology with a broad range of applications in many contexts and at several levels of analysis. The methodology is appropriate for structuring the information dimension of practically any decision oriented system, or subsystem depending on the frame of reference, from a family budget or university curriculum to a national economy or a space program. The relevant system may be highly structured and formal or unstructured and informal; it may involve rigorously defined quantitative relationships or vague qualitative judgements. The system may be complex or simple, significant or trivial; it may relate to people, institutions, industries or nations. It is because the information systems process is a methodology rather than a solution technique, an approach rather than a set of prescribed answers, that it can be applied meaningfully to such a broad spectrum of systems.

While this discussion is based in the general methodology of information systems analysis, it is particularly concerned with the special characteristics, dimensions and extensions of the process required in the advanced management environment outlined in Chapter I. In this context, we are dealing with large-scale, complex systems involving the interaction of numerous interdependent subsystems and decision processes. It is assumed that operations research and computer technologies have been applied at an operating systems level and that management has achieved some degree of sophistication with systems concepts and objectives.

At this level of development, the significance of interactions among locally optimized decision processes may far outweigh the significance of more precise local optimization. The major contribution of information systems analysis in this context is the integration and structuring of diverse decision criteria, models and technologies to more effectively achieve total system objectives. Accordingly, we will be concerned primarily with information and measurement requirements reflecting the impact of interactions and interdependencies among decision processes upon total system performance.

These requirements necessarily involve large segments of the organization and demand a broad systems orientation throughout the analysis process. The existence of state of the art operating decision models and the resources required to develop, implement and maintain these models are defined to be part of the relevant environment. Therefore, the following discussion of information systems activities may draw freely from appropriate management science technologies without laboring over their development or implementation. It is the impact of interactions among these technologies, decision models etc. upon total system objectives that will be of primary interest. In essence, we are concerned with attaining a total systems perspective, effectively structuring systems relationships, identifying and defining information requirements and developing a measurement system adequate to operationalize these requirements. The methodological base for achieving these objectives must be sufficiently broad to incorporate relevant management science models; but the underlying objective is to structure, integrate and evaluate the contribution of these models in a total system context rather than dwell on local optimization problems.

These objectives impose extended requirements on the systems analysis and measurement system aspects of the information systems process. An integrated system model encompassing large segments of the total system is required to analytically structure interdependent decision processes and meaningfully represent their relation to the total system. A relevant measurement system capable of operationalizing the interrelationships among decision processes across large segments of the total system is required to evaluate the impact of local decision variables in terms of total system objectives. These requirements demand an integration of diverse decision models, operating systems, resources, objectives and constraints which seldom has been achieved in real world applications.

The significance of these requirements and their crucial relation to the achievement of information systems objectives in an advanced management environment suggests the need for an expanded methodology for system modeling and measurement. The principles and problems encountered in the organization review and implementation aspects of the information systems process are largely independent of these extended requirements except at their interface with the systems analysis and measurement activities. Accordingly, the following discussion focuses primarily on the systems model and measurement system and considers only relevant implications for the related areas.

The following chapters examine a methodological base for systems modeling and measurement. The emphasis on methodology is consistent with the objectives and requirements of the information systems process. The objective is not to develop a solution technique or a packaged technology, but rather to suggest a method for achieving an operational systems orientation in a significant ongoing organization. The approach is essentially conceptual, but the emphasis is on application in the sense of developing operational extensions to existing systems. It is not enough to merely set forth a theoretical framework. It must be shown that the methodology is feasible and effective in achieving information systems objectives in a live context. For this reason, the conceptual development set forth below is applied to a real world organization in an expanded field study presented in Chapter V.

III. SYSTEMS ANALYSIS AND CONCEPTUAL MODEL BUILDING

STATE OF THE ART

The potential of large-scale computer modeling as a methodology for analytically structuring significant organizational relationships has been explored in the literature since the late 1950's. Prior to that time the technological base required for meaningful work in this area was not available. In 1963, Charles P. Bonini in Simulation of Information and Decision Systems in the Firm[1] presented a macro-representation of a hypothetical firm which constituted something of a milestone in computer modeling and simulations. Bonini's contribution essentially was the demonstration of the technical feasibility of simulating a business organization at a highly conceptual level. Bonini's work focuses on a theoretical model of the firm; he did not undertake to develop the methodology of computer modeling and simulation as an applied management science tool.

A substantial quantity of literature addressed to technical problems in computer simulation appeared during the 1960's. Considerable effort was directed to the development of random generators, stochastic processes, efficient search procedures and special purpose compiler languages such as GPSS and SIMSCRIPT. The primary focus of applied work during this period was concentrated in the operations research area deriving solution models for analytically intractable problems such as job shop scheduling, queueing systems and game theory. In large measure, these efforts dealt with simulation as a solution technique for specific problem areas with little attention to the broader systems context.

Jay Forrester's work in Industrial Dynamics[2] was one of the first significant efforts to examine the potential of computer simulation for large-scale systems modeling and analysis. In retrospect, Forrester's contribution was more directly related to the development and articulation of applied systems concepts and an examination of systems modeling in general than to computer modeling and simulation per se. The DYNAMO "simulation" compiler which Forrester designed to be compatible with his macro-flow representation of systems activity has found little application or support outside of his own work.

Perhaps, the most important result of Forrester's work in the context of information systems analysis was the demonstration that total system relationships can seldom be deduced directly from an examination of the component parts of the system. The significance and complexity of interactions among various subsystems, decision processes and organizational characteristics require some form of integrated systems model to relate local decision variables meaningfully to total system objectives and performance.

Outside academia, some interest in large-scale system modeling and simulation of industrial organizations began to develop in the mid 1960's. A 1966 survey conducted by William Vatter[3] found that a marked increase in the use of management science models began in 1963. A more recent survey by George Gershefski[4] in 1969 reported that among member companies of the Planning Executives Institute more than 100 corporate models were in use under development and that the majority of these were computer simulations reflecting a broad view of the company. The survey indicates a major increase in modeling activities in 1966 and suggests that a substantial proportion of the projects reported are still in the initial stages of development.

LIMITATIONS AND EXTENSIONS

These surveys reflect an applied state of the art among advanced mangement groups which is pressing beyond theoretical and conceptual work in the systems modeling and simulation area. This movement is motivated, in part, by continuing management involvement with current computer technologies resulting in a level of awareness and technical expertise which surpasses that of many academic or theoretically oriented groups. The availability of computer and management science resources at relatively low marginal costs in an advanced management environment has spurred the development of applied approaches to significant systems management problems. To an increasing degree advanced management groups have recognized the significance of systems relationships and the interactions among decision processes; however, conventional systems models and measurement systems have proven inadequate to structure and operationalize these management requirements.

This concern with total system relationships and the ability to commit significant resources to systems analysis activities are important attributes of an advanced management environment. The current development of integrated systems models capable of evaluating total system relationships represents a new generation of applied management science. Previous advances in management science commonly have involved the application of new theoretical models or analytic tools.

These applications required finding meaningful problems appropriate to the theoretical model and developing new technologies to implement the solution technique in a live context. Applications of linear programming during the past 20 years have followed this pattern.

Current advances in systems modeling and measurement follow a different pattern. Application oriented groups armed with large-scale resources and sophisticated technologies are attacking significant management problems on an empirical basis with little theoretical foundation or structured methodology. While this approach may produce significant results in specific applications, it possesses a number of potential weaknesses and limitations.

The quasi-proprietary nature of systems analysis activities developed with private resources and possibly involving confidential information creates a communication barrier among management groups working on essentially similar problems with similar objectives and resources. As a result, many of the mistakes, trials and errors made in 1966 may be repeated in a different context in 1970 or 1975. In the absence of general criteria for (1) when and how to approach integrated systems modeling and measurement, (2) what to expect and (3) what not to expect, numerous false starts involving unproductive commitments of substantial resources may immune many management groups to future efforts and outside developments in the area.

Perhaps the most significant limitation of approaching large-scale systems analysis through applied, technically oriented groups is the difficulty in maintaining total system objectives and awareness. The background, responsibility and operational interest and perspectives of these groups are directed toward specific problem solving applications. As a result, there is a strong tendency for broad systems considerations to be lost or abandoned in favor of more immediate problems and applications. This tendency constitutes an analogy to Gresham's Law of currencies in economics which is often alluded to in the literature of long-range planning and innovation. Long-range, broad objectives tend to be displaced by less significant, but more pressing problems which may be better defined, more manageable and more directly related to short run measures of performance.

In order to realize the potentials of large-scale computer modeling and simulation in the context of information systems analysis discussed in the preceding chapter, a general framework of objectives, requirements and methodology is required. Unique organizational resources in management expertise and experience, operations research and systems capabilities and computer hardware and software systems must be integrated in a flexible, adaptive framework to achieve effectively broad systems objectives. It is important to recognize that this framework, like the information systems process, is itself a system and must be approached accordingly. While specific elements of the framework are discussed separately below, their significance lies in their relation to the total process. A fundamental tenet of this thesis is that the total modeling and analysis system represents much more than the sum of its parts. Significant information and measurement requirements involving broad systems questions can be resolved only through a high level analysis which requires the structuring and purposeful integration of diverse organizational resources and capabilities. Computer modeling and simulation represents a powerful vehicle for structuring such a high-level analysis, but clearly the scope of the analysis system extends significantly beyond computer simulation technology per se.

PERSPECTIVE AND OBJECTIVES

The underlying objective of the systems analysis process is to formally, analytically understand or comprehend the total system and the relation of individual components, subsystems and functions to total system criteria. In large-scale, complex systems, such as significant business organizations, this objective can never be fully realized. The size, complexity and rapid rate of change of these systems prohibit comprehensive, detailed specification of systems relationships in any meaningful sense.

Accordingly, the operationalization of this objective in a significant context requires an adaptive methodology capable of heuristically exploring relevant systems relationships on a continuing basis. At the present state of technical development, computer modeling and simulation can serve as an effective methodological base for pursuing this objective.

Several fundamental characteristics and capabilities of the computer modeling and simulation process are particularly relevant and useful in the context of large-scale information systems analysis. The formal, analytic language of program flow charts and computer logic is rigorously defined and well documented. This language system provides a uniform communication base by means of which systems structure and relationships can be meaningfully represented and transmitted among organizations, organizational units and over time. Such a rigorous, uniform communication base is a minimum requirement for effectively integrating diverse organizational units and resources in the systems analysis process.

Technical work in computer hardware and software support for modeling and simulation during the 1960's has provided a broad base of well documented, readily available capabilities. Special purpose compilers and well developed analytic methods have substantially reduced the resource requirements for large-scale modeling efforts while significantly increasing the analytical power and flexibility of simulation activities. At the present state of the art, substantially any operations research model, deterministic or stochastic decision rule, can be incorporated into a computer model and evaluated in the total system context through simulation. This capability serves to (1) free the systems analyst from rigid commitments to specific operations research models and (2) facilitate the evaluation of alternative decision rules and criteria.

The system model constitutes the analytic structure for simulation based measurement and evaluation. The simulation process consists of evaluating the impact of system design, policy and decision variables upon total system criteria by experimenting with these variables in the system model and monitoring changes in model performance.

The overriding strength of this approach is the ability to operationally define and execute measurement requirements in the total system context. Resulting interactions among local decision processes, analytic models and policy and system constraints can be fully evaluated in terms of total system criteria. Furthermore, the measurement process can be replicated over a range of relevant system parameters, assumptions and contingencies to test sensitivities and establish confidence levels.

This broad flexibility of computer modeling and simulation as an analytic methodology allows the systems analyst to experiment imaginatively with system design, decision model or policy alternatives, not in a local vacuum, but within a meaningfully comprehensive and structured systems context. In this manner, the analyst can explore complex planning and control alternatives heuristically with an evolving system model rather than a rigid analytic framework which may become irrelevant or inappropriate as the analysis unfolds.

The systems model may evolve in several dimensions over time. The model must grow with the system to reflect changes in organization and operations. Similarly, the model must evolve to accommodate new measurement requirements associated with changing decision criteria, alternatives and perceived problems. New analytic methods or operations research models may be introduced to restructure existing decision rules. Finally, changes in the environment or assumptions about the environment as well as the organization's objectives, resources and constraints may suggest modifications in the model or in the scope and direction of the analysis.

The adaptive flexibility and evolving heuristic structure of computer modeling and simulation provide an operational basis for pursuing the objectives of the systems analysis process outlined above. The underlying perspective or philosophy of these objectives is important for understanding the analysis process and evaluating the contribution of an analytic methodology. The philosophy of the analysis process is concerned more with operationally determining significant questions in the total systems context than with formulating precise answers. The analysis process is exploratory and diagnostic; it seeks to establish an operational understanding of total system relationships rather than implement specific changes or normative models. In this sense, the systems analysis is neither planning or control; rather it is concerned with building a valid foundation from which planning and control systems can be derived.

The perspective of the analysis process implies a broad, flexible, open-minded approach to system modeling. Rigid preconceptions with respect to specific local decision processes, performance criteria and problem areas must not predetermine their relation to the total system. The objective clearly is not to build locally conceived conclusions into the model, but rather to evaluate local alternatives in relation to the total systems context. This precept derives from and reinforces the underlying objective of establishing an operational base for understanding and evaluating total system relationships. This approach is in contrast with other approaches that tend to pursue immediate applications in a systems vacuum.

This philosophy does not imply a random or purposeless approach to systems modeling. The structure of the analysis and modeling process parallels the information systems analysis process discussed in Chapter II. The function of computer modeling and simulation in this process is to establish an operational basis for structuring the analysis in the total systems context. Computer simulation provides an operational measurement base for analytically exploring and evaluating decision processes, information requirements, planning and control systems, data base requirements and policy alternatives as they interact in the total system..

The analysis process is heuristic and proceeds in an iterative, spiral fashion. Initial assumptions and observations are modeled to represent systems structure and relationships. Simulation is then employed to explore the implications of the systems model. Organizational structure, policy constraints, decision models and information requirements may be tested for the sensitivity and significance of their impact on total system criteria. The results of these measurements are then evaluated to identify critical elements in the system structure which may be modified or enlarged to provide the basis for a refined system model.

Again, this level of analysis is directed to the identification of significant systems variables and the structuring and evalutaion of these variables in the total system. While various operations research techniques may be incorporated in the modeling and measurement process, the primary objective of the analysis is not merely to optimize local decision processes. Computer modeling and simulation provide a useful methodological base for structuring this level of analysis in the information systems context.

MINIMUM SYSTEMS REQUIREMENTS

The perspective and objectives outlined above imply that a certain degree of systems development and sophistication is required before a high level analysis is relevant or appropriate. This qualification is consistent with the concept of an advanced environment as set forth in delimiting the scope of this inquiry in Chapter I.

The preceding sections have discussed a number of interrelated problems and management requirements associated with complex systems characterized by significant interactions and interdependencies among local objectives, decision processes and performance criteria. In this context, the impact on total system criteria of interactions among various systems variables may be more significant than their direct effects. The need for an operational analysis and measurement system encompassing the total system was based upon this premise.

An organization which has not yet developed basic operating systems may face a different hierarchy of problems and requirements. The need for specific operating systems, (such as inventory systems, production systems, logistics systems) or even specific decision rules, (including reorder points, scheduling routines or routing methods) may directly influence total system performance so significantly that interaction effects are reduced to an irrelevant status. In this context, local optimization models may contribute more to total system objectives than a high-level analysis seeking to coordinate interacting subsystems, some of which do not yet exist. An organization at this level of systems development is not part of the advanced management environment discussed in Chapter I.

The concept of an advanced management environment presumes the existence of ongoing operating systems. The high-level information systems analysis seeks to integrate the functioning of these operating systems to more effectively achieve total system objectives.

The high-level analysis can be applied before operating systems are developed; however, this will rarely be the optimum sequence for business organizations. Premature efforts in this respect are analogous to polishing a gem before it is cut. Significant resources may be effectively wasted in the process and poorly based conclusions may seriously misdirect or impair future efforts.

Successful design of "total systems" from scratch may be feasible under unusual circumstances such as establishing a new governmental agency or corporate division. The methodology of computer modeling and simulation may prove to be very useful in these cases. However, the success of the analysis and design process will depend heavily upon the availability of prior experience with similar systems and the ability to anticipate systems requirements and relationships completely and accurately. While important cases of this type may be encountered, particularly in the context of urban and environmental planning, they derive from unusual circumstances which lie outside the scope of this inquiry.

The existence of ongoing operating systems implies a level of systems development that has progressed beyond a "brush fire" approach to operations research and computer applications. This systems sophistication consists not only of well developed hardware and software applications, but also a degree of management experience and competence with systems concepts and objectives.

The objectives and requirements of the information systems analysis process demand a management perspective which is highly systems oriented. Just as meaningful long range planning must involve more than an exercise in pro forma financial statements, the systems analysis process demands more than an exercise in corporate modeling or a meaningless statement of "corporate objectives."

The systems analysis is a heuristic process seeking to explore total system relationships and operationally structure these relationships in a decision relevant system. This process demands a degree of managerial and organizational maturity in systems development in order to recognize significant systems relationships and interpret these relationships in terms of total system criteria. The development of this capability, both in its technical and conceptual dimensions is an evolutionary process which varies with the nature of the organization and its environment. In this context, the existence of well developed, reasonably stable operating systems represents a minimum criterion for achieving the objectives of the high level analysis process.

ORGANIZATION REQUIREMENTS

The total system analysis is concerned with a higher systems level than that encountered in the analysis and design of operating systems. Objectives, resources and constraints taken as given in the context of local operating systems may be variable or discretionary at this higher systems level. The analysis of relationships at this level cuts across conventional organizational and functional boundaries and must evaluate the impact of interactions among these subunits upon total system criteria.

The high-level analysis requires a significant commitment of organizational resources in a long-range time frame. The alternatives and decisions involved at this level of analysis are significant in the total systems context and demand long-range continuity in analysis and execution. The integration of diverse operating systems and decision processes, implying a displacement of local decision criteria by total systems criteria, requires a high degree of effective management coordination and communication throughout the analysis process.

These characteristics and requirements suggest a need for a specialized organizational unit capable of supervising the analysis process on a continuing basis and executing derived recommendations and conclusions. At the operating systems level, technical expertise has often formed the single overriding criterion for defining such organizational units. As a result, these "systems groups" have been comprised primarily of technically oriented people in the operations research and computer systems areas.

At their appropriate systems level, these groups have contributed significantly to realizing the potentials of technical innovations in systems design and management. Indeed, an effectively functioning systems group is an essential resource in an advanced management environment. However, the structure and orientation of the conventional systems group is not adequate for the high-level analysis.

The objectives and requirements of the high-level analysis demand top management involvement on a continuing basis. Total system authority and responsibility are prerequisite for achieving a true global perspective of organizational objectives, resources and constraints. The attainment of this perspective requires the capability of moving beyond internal systems constraints and organizational barriers to a higher systems level where total system relationships can be structured and analyzed. A quasi high-level analysis lacking top management involvement is prone to incorporating apparent objectives and constraints into the systems model resulting in significant suboptimalities and misconceptions at the total system level.

Top management commitment is required to provide long-range support and execution of systems analysis activities. The high level analysis is a significant undertaking which may not immediately or directly benefit specific operating areas or organizational divisions. Only at the total system level accessible to top management, can the total benefits and costs of the high-level analysis be appraised in an appropriate systems context and time frame.

While top management participation is required to achieve an appropriate systems orientation, the functional expertise and operating experience of middle management at the operating systems level are necessary elements in the high-level analysis process. An understanding of total system relationships and the interactions among operating systems must begin with a specification and analysis of functional requirements and their operationalization in the systems context. Operating systems management contribute to the analysis in the specification of decision processes and information requirements deriving from total system objectives, resources and constraints.

This middle management group represents the link between the resources and capabilities of the advanced management environment and the objectives of total system management. This group is also the link between current and future operating systems, the immediate vehicle through which change will be implemented. Both from an organizational and technical standpoint, the active participation of this group is essential to the analysis process.

The conventional systems group possesses the technical expertise and systems design experience required to support the analysis process and implement specified recommendations. While the systems group may have had primary responsibility for designing operations research and computer applications in the evolution of the advanced management environment, its role in the high-level analysis essentially is supportive. The systems group is drawn upon to provide a technical base in such areas as computer modeling, statistical analysis, decision theory, formal systems analysis techniques and evaluation of hardware and software capabilities and constraints. Beyond this supportive function, the systems group may assume primary responsibility for implementing proposed changes or extensions to existing operating systems in the post analysis phase.

The high level analysis requires the unique contribution of representatives from top management, major operating systems and the systems staff. The background, experience and expertise of these groups must be effectively integrated to achieve high level analysis objectives. This integration requires a common conceptual framework and structure of analysis to establish a basis for effective communication and coordination throughout the analysis process.

Computer-based corporate modeling provides this common conceptual framework and, through simulation, establishes a measurement base for total system analysis. The modeling and simulation process establishes both a structure of analysis and a methodological base for pursuing analysis objectives.

The integration of relevant management and staff groups through this framework serves several important functions. Top management perspective of organizational objectives and middle management experience with ongoing operating systems are explicitly related in a rigorous systems model. This model represents a common base for systems definition and analysis. The operationalization of the model through computer-based simulation provides a flexible, heuristic structure for exploring systems relationships in the total system context. Thus, the systems model is directly implemented as a measurement system capable of evaluating relevant alternatives in the meaningful context.

The essential continuity of the analysis, modeling, measurement and evaluation activities emphasizes the need for broad organizational involvement throughout the process. Specific activities cannot be broken out and executed by independent groups. The unique expertise of the top management, middle management and systems groups must be applied in concert. This organizational dimension of the high-level analysis represents an essential requirement for pursuing total system objectives in an advanced management environment. In this context, the process of analysis through modeling and simulation provides a structure of education, communication and systems definition through which this requirement can be achieved.

IV. SYSTEMS ANALYSIS THROUGH COMPUTER MODELING AND SIMULATION

The dual nature or two sides of the analysis process were discussed in Chapter I and II as a system model and a measurement system. The essential relation between these aspects of analysis is often obscured. The significance of this relation derives from fundamental, but crucial, concepts of definition and measurement. The system model constitutes a framework of definitions pertaining to systems objectives, relationships, and performance criteria. The measurement system seeks to quantify these concepts in the ongoing organization.

The relevance of the definition system and the extent to which it can be operationalized through a measurement system determine the usefulness of an analytic framework. Irrevelant or nonoperational concepts do not satisfy information requirements.

The conceptual approach to systems modeling discussed in this paper derives from the principles of information systems analysis which seeks to identify relevant information requirements. The translation of the conceptual model to computer logic creates an explicit, operational definition system in a uniform, integrated medium. Analysis of system structure, parameters and variables is accomplished by experimental simulation of systems performance through high speed computer execution of the operational system model. The computer-based model constitutes both a system model and a measurement system due to its conceptual base and operational structure.

In the following sections, selected elements of the conceptual analysis process underlying the development of the systems model will be examined. Methodological implications regarding the role of the systems model in the high level analysis also will be discussed. These concepts of systems definition and modeling will then be explored in the context of a live field study in Chapter V. Operationalization of the system model as a computer-based measurement system is the subject of Chapter VI which continues in the context of the field study project.

HIGH-POINT ORGANIZATION REVIEW

The broad objectives of the organization review phase of the analysis process were discussed in Chapter II. That discussion emphasized the dynamic, open-ended nature of the organization review and the need for a systems model capable of accommodating changing assumptions and perceptions of the organization-environment interface.

In the context of conceptual model building for the systems analysis process, the organization review consists of defining the boundaries and parameters of the relevant system. This systems definition determines which aspects of the organization and its environment will be considered as fixed or given and which aspects will be modeled as policy or decision variables. These determinations implicitly specify the systems level of the analysis process and may significantly constrain both the nature and content of ultimate conclusions.

Accordingly, top management, perhaps with the assistance of outside consultants, should play a dominant role in this phase of the analysis. Only at this level can the total system be conceptualized meaningfully with a minimum of spurious constraints and preconceived, locally derived conclusions.

The contribution of the outside consultant is to provide a broad structure of analysis and maintain an appropriate systems level. The analysis may be structured around an identification of the organizations objectives, resources and constraints in relation to its present and anticipated future environment. At this level, implications should not be pursued through specific operating systems or organizational units. Premature crystallization of conclusions or recommendations may defeat the purpose of the analysis process.

The identification of system objectives, resources and constraints must be as specific and operational as possible. Documentation through the use of flowcharts, diagrams or other modeling devices may be helpful in maintaining a consistent perspective and forcing more complete articulation of various concepts and relationships. Of equal importance, however, is the maintenance of a flexible methodological base free from commitments to specific preconceived models. The high-point analysis is the first step in an iterative process seeking to develop an appropriate systems model. Except in unusual, highly structured cases, this effort can be slowed or misdirected by attempting to fit the system to an established model.

Operational specification of system characteristics and relationships may be facilitated through systematic inquiries into the nature of the business, its markets, products or services, customers, competition and legal or regulatory constraints. Often an identification of significant profit centers or profit generation streams provides a useful framework for exploring system relationships. In the case of nonprofit organizations, measure of services performed may be substituted for profit generation. This approach serves to highlight significant system activities and provides a basis for operationalizing system objectives, resources and constraints.

A broad input-output analysis also may be a useful device for structuring the initial high-point analysis. The objective here is to specify the major resource flows available to the organization, (such as raw materials, labor, management skills, capital and information) and the major outputs produced by the organization (including products or services, information, funds, and perhaps, pollution). The interaction of inputs or resources constitutes constrained system activity which seeks to produce an output set consistent with the organizations objectives. Meaningful specification of these relationships provides a basic structure for defining relevant system characteristics in relation to operational concepts of objectives, resources and constraints.

As the system model is developed and utimately operationalized through simulation, the concepts and assumptions incorporated in the organization review may be tested for sensitivity and implications for total system performance. The underlying analytic perspective or systems viewpoint may be modified repeatedly as the nature of the system and its behavior is more fully understood. An important aspect of systems analysis through modeling and simulation is the potential for exploring the implications of implicit assumptions or constraints which may be so much a part of the systems viewpoint that they have not been examined or even articulated explicitly. In this context, a primary objective of the analysis process is to discover and explore significant questions or alternatives affecting total system performance rather than to prescribe optimal solutions or normative models.

EXAMINATION OF OPERATING SYSTEMS

The next step in the analysis process is the identification of the major operating systems required to operationalize the systems activities defined in the organization review. These systems constitute the "housekeeping functions" which dominate system activity below the strategic planning area. The operating systems comprise the functional link between the organization's resources and objectives.

The boundaries and structure of the operating systems must be determined by the nature of the organization and its environment. While it may be useful to differentiate production, marketing, personnel or financial systems for pedagogical purposes, these concepts may not correspond to actual system structures in specific organizations. The functions encompassed by operating systems are primarily transactions (external and internal) oriented. Accordingly, flowcharts or diagrams representing the major transaction flows required to support the organization's objectives in relation ot its environment may provide a conceptual framework for exploring and specifying the characteristics of specific operating systems.

The existence of well developed operating systems has been predicated as an essential element of an advanced management environment. As a result, this discussion is not directly concerned with the development of operating systems, but rather with the interaction among operating systems in relation to total system objectives. In this context the examination of operating systems in the conceptual model building phase of the analysis process should be greatly facilitated by existing documentation. Representatives from the systems group would actively participate in the organization and analysis of this documentation for the high-level systems study group.

Modeling of existing operating systems does not imply that these systems are fixed or constitute constraints on the total system model. The approach to high-level analysis through computer modeling and simulation provides an operational methodology for evaluating existing subsystems in the total system context as well as experimentally evaluating alternative subsystems through an evolutionary process of model modification and simulation.

The strength of this approach derives from two underlying premises. First, it is substantially never possible to specify an optimum systems configuration in a complex organizational setting _a priori_. Accordingly, a systematic methodology for systems evolution paralleling new technologies and organizational changes is essential. Second, an operational methodology for large-scale systems analysis and design in the context of an ongoing organization must relate to existing systems and operations. This is essential both from a diagnostic standpoint, i.e., will a systems change improve total systems performance, and from a systems development standpoint, i.e., how to move from an existing to a proposed systems configuration.

The critical aspect of this stage of the analysis process is not to specify optimum operating systems, but rather to relate operating system functions and activities to the total organization model conceptualized in the organization review. Again, the objective at this stage is to develop a framework for high-level analysis, not to optimize a local decision process or transaction flow.

IDENTIFICATION OF MAJOR DECISION PROCESSES

Both from a conceptual and an operational standpoint, the high-level analysis is decision oriented. Information requirements and relevant measurement systems addressed to these requirements can only be defined in terms of decision processes which relate the organization's resources to its objectives.

An emphasis on decision processes has permeated much of the professional literature in management science for more than a decade. However, in the context of the high-level analysis the overriding objective is to specify the decision processes required to operationalize total system objectives rather than to optimize a given decision process. The systems group, which is an essential element of the advanced management environment, is responsible for maintaining an advanced expertise in operations research and related management sciences and for applying these technologies in the organization's decision processes on a continuing basis. But the high-level analysis is concerned with specifying these decision processes and the relationships among them in terms of total system objectives and performance. This objective is much broader and ultimately of greater impact than specific decision models or solution techniques.

Numerous check lists, descriptive models and classification schemes have been proposed to structure the identification and analysis of decision processes. Frameworks built around functional processes, conceptual systems models (Katz and Kahn)[1] and characteristics of decision processes (Anthony)[2] are common in the literature. While these frameworks provide a useful "world view" for structuring research and analyzing decision systems at a conceptual level, they do not provide an adequate methodological base for the high level analysis process.

Meaningful identification and analysis of decision processes must derive from a comprehensive understanding of the specific organization involved and its environment. No general check list or theoretical model can provide a substitute or significant short cut for the required analysis and understanding of the organization and its environment. A commitment to preconceived models or classification schemes may, in fact, result in a too narrow or restricted perspective which may ignore significant relationships or superimpose conclusions which are not appropriate to the situation.

This does not imply that the analysis process must be left to intuition, unstructured experience or random approximations. The approach to systems analysis through computer modeling provides a comprehensive framework within which diverse management experience and insights can be systematically structured, analyzed, and, perhaps, modified.

Computer-based modeling represents a common framework with no significant preconceived constraints or conclusions. The methodology is iterative, heuristic and entirely contextual. Yet the approach is highly structured in the sense that assumptions, constraints and relationships must be explicitly set forth in a common language and related to the total system. Unspecified or previously unidentified relationships produce gaps in the logical structure which must be closed explicitly by assumption, policy decision or extended analysis. Those unique aspects of the system which lie outside a theoretical model or classification scheme are not excluded from the analysis.

The process of computer modeling within the high-level analysis is, therefore, essentially a process of identifying and analyzing the decision requirements which structure the organization's activities within an environment context. Furthermore, the formal modeling process provides an envolving framework for explicitly specifying and analyzing interrelationships among decision processes throughout the organization.

This emphasis on interaction effects was stressed as an essential element of the high level analysis. Wholly conceptual or intuitive approaches to decision analysis often fail to achieve this objective which differentiates the high-level analysis from conventional "systems analysis" concerned more with local optimizing techniques and operating systems or subsystems. The formal analysis process provides both an integrated conceptual framework and an operational structure of analysis and communication to pursue this objective effectively.

The operationalization of the formal model through computer simulation establishes a basis for exploring the integrity and implications of specified decision systems and interrelationships. This operational basis is essential for meaningful systems definition, analysis and heuristic evaluation of alternatives. While abstract, normative systems models may be useful initially in the conceptualization of broad systems relationships and general guiding principles, meaningful diagnostic and system design conclusions must be related operationally to the specific decision processes and information requirements of the ongoing organization.

The very significant and difficult area of model validation is directly addressed in Chapter VI; however, it may be useful to consider some aspects of this problem in relation to the role of an operationalized model for the definition and analysis of decision processes. To a significant degree, the explicit modeling of decision systems does not create a validation problem but rather brings a continuing and persistent question of validity very powerfully into the open.

Explicit modeling and simulation compels operational articulation of relationships which previously may have been unidentified or loosely defined in general, poorly specified terms. If a specific model element or operationalization is challenged, it can be reevaluated, perhaps modified and reasserted. This constitutes the very methodology of heuristic systems definition and analysis.

But if the relationship is not operationalized, its validity may not be subject to challenge. Moreover, the potential contribution of both the poorly articulated hypothesis and its alternatives are greatly diminished. Operational modeling creates a vital vulnerability to challenge, and also provides a vehicle for explicitly testing validity and evaluating alternative conclusions.

IDENTIFICATION OF INFORMATION REQUIREMENTS

Analysis and design of management information systems must derive from an understanding and operational definition of management information requirements. This specification of information requirements, in turn, is based upon an analysis of decision processes required to effectively pursue total system objectives within an environmental context. The specification of information requirements is neither static nor unique; it must derive from a continuing, dynamic, heuristic analysis of decision processes and interactions as the organization and its environment evolve through time.

The high-level analysis within an advanced management environment is concerned more with interactions among decision processes and operating systems than with optimizing local decision models and programmed decision rules. The resources and orientation required to pursue these latter objectives have been posited as an essential enabling element or technical precondition to the advanced management environment. Accordingly, the high-level analysis seeks to build upon these resources and capabilities rather than reinventing them.

The operationalization of interdependent decision systems in the total system model provides an explicit basis for assessing the impact of specific decision criteria, policy specifications and systems structures as well as their interaction effects upon total systems performance. At a first level of analysis, extensive sensitivity testing of existing systems parameters and specifications provides a vehicle for defining previously unidentified decision areas or alternatives involving total system interactions. This process is iterative and heuristic, perhaps involving modifications and extensions to the system model as the analysis progresses.

This approach to the analysis of decision systems facilitates identification of significant areas for further inquiry. Because the high level analysis is a heuristic process rather than the application of a normative model, the identification and evaluation of significant systems alternatives is essential to the methodology. This process of analysis provides a basis for defining and ordering appropriate steps in the analysis, design and implementation of systems changes.

By concentrating first on areas with the highest expected yield in terms of total system performance, a more efficient allocation of systems analysis and other organizational resources can be attained. This process also can be applied hierarchically within the analysis of selected areas or systems modification alternatives. While the concept of rank ordering may be difficult to fully operationalize because of conflicting or competing system performance criteria, the elimination or deferral of clearly low yield alternatives could contribute significantly to the effectiveness of the analysis process.

The ordinal ranking of systems alternatives in terms of simulated impact on total system performance can be related to cardinal measures of information value, at least at discreet points. Perfect information or multi-decision optimization can be represented within the simulation to derive an approximation to the value of perfect information in terms of total system performance. This potential impact on total system performance represents a crude measure of the value or significance of improved decision systems and information flows in specified areas.

Given the identification of significant areas for potential system modifications, the operationalized system model provides a measurement base for assessing the degree to which proposed alternatives derive the potential impact on total system performance. Furthermore, because this measurement system derives from a representation of the ongoing organization, proposed alternatives are evaluated within the context of existing constraints, uncertainties and imperfections. Again, the essential relationship between the system model and the measurement system must be stressed. The impact of systems alternatives is measured operationally in a live context rather than through a theoretical model. What this approach may sacrifice in precision and closed analytic appeal, it gains in decision relevance and transferability to the ongoing system.

An important aspect of simulation based measurement, implicit in the preceding discussion, is the ability to represent dynamic system behavior over time. Fixed equilibria and static optima are seldom a satisfactory representation of significant live systems. The interaction of complex decision processes and information flows involves feedback configurations and stochastic relationships which can be meaningfully evaluated only as a dynamic pattern of behavior. The information systems analyst must be concerned with more than simple expected values, time independent relationships and aggregated system performance. The exceptional cases, the tails of joint distributions and micro time phased systems relationships are of particular concern in the high-level analysis where programmed decision rules have already been implemented to deal with bulk transaction flows. Simulation based measurement with graphic display capabilities is an effective vehicle for exploring dynamic behavior patterns derived from empirical system representations.

Beyond the function of providing an operation measurement base for evaluating alternative information flows and system configurations, elements of the system model may be incorporated in the resulting information system as a data transformation vehicle addressed to continuing decision information requirements. Applications involving job shop scheduling, distribution assignments and queueing problems are commonplace at the present state of the art. More advanced applications in long range planning, resource budgeting, evaluation of competitive strategies and guiding dynamic organizational structure are very real possibilities which represent logical outgrowths of the systems analysis through modeling and simulation methodology.

V. APPLYING THE FRAMEWORK IN A LIVE CONTEXT

A major objective of this study which has been emphasized in the preceding chapters is to outline and evaluate an appropriate modeling and measurement methodology within the high-level analysis process which can be meaningfully applied in the context of an advanced management environment. The approach through computer modeling and simulation outlined above has been characterized as highly operational and capable of relating the analysis process to the existing organization while providing an effective basis for heuristically exploring systems alternatives and modifications in several dimensions.

By the very nature of this objective and the proposed methodology, the development of a basis for meaningful evaluation demands more than a descriptive or theoretical framework. Empirical evidence of the feasibility and effectiveness of the proposed methodology in a live context is required.

At the present state of the art, both with regard to the requirements of an advanced management environment and the availability of large-scale computer modeling resources, it is not surprising that very few attempts to apply even a facsimile of the proposed methodology can be identified. Accordingly, a survey of existing applications is not feasible except at a highly abstract level which would not serve the present purpose.

Applications which can be identified have been highly conceptual or addressed to specific problem areas with restricted scope and objectives. Modeling and simulation efforts in the areas of production, scheduling, distribution systems and financial planning have contributed to available technology and technical experience but relate only tangentially to the broader objectives of the high level analysis process. Case studies in these areas may be useful in terms of technical orientation, but would contribute little to the understanding or evaluation of the broader methodology.

Given these constraints, the approach chosen for this study is to initiate a high-level analysis through computer modeling and simulation in a significant, ongoing advanced management context. The objective of this effort is to identify and evaluate the problems, potentials, requirements and characteristics of the proposed methodology in a real world application. This inquiry is intended to be exploratory in nature. It is not presumed that results obtained in one application can be generalized indiscriminately but rather that evaluation of a methodology in a live context represents a significant and necessary extension beyond a descriptive framework. By this means an operational basis can be established to identify and meaningfully evaluate significant dimensions of the proposed methodology.

The scope and magnitude of the high-level analysis process have been discussed in preceding chapters. This discussion has emphasized the large commitment of management and other organizational resources required to effectively pursue high-level analysis objectives. The high-level analysis has been presented as a long-term, continuing process involving heuristic interactions and refinements as the system and the analysis evolve over time.

These requirements effectively prohibit the development of a fully operational application within the bounds of this study. Furthermore, in relation to present objectives, a fully developed application is neither necessary nor particularly desirable. At the current state of the art, an operational identification and evaluation of the major dimensions and attributes of the methodology represent a more significant research area than detailed specification of technical requirements and results. A fully operationalized application would require inordinate emphasis on these technical aspects at the probable expense of more significant methodological questions and meaningful generality.

Accordingly, the live context study presented in this chapter is not presumed to represent a full scale demonstration or fully developed application. Rather, it represents an operational inquiry into selected dimensions of the high-level analysis process within the context of a significant real world environment. The study was structured as a high-level analysis, but the direction of specific inquiries has been heuristically guided to explore significant methodological areas as they were encountered.

After a brief description of the organizational environment underlying the study, selected aspects of the organizational review and conceptual model building process are examined. Identification of data requirements and data gathering and processing activities are then explored as an outgrowth of the conceptual model building process. Significant aspects of the computer modeling process are examined in three phases: (1) hardware and software requirements, (2) design of the simulator, and (3) model integration and implementation. Following an analysis of model validation requirements, decision relevant application areas are explored in relation to the contribution of the modeling and simulation process.

ORGANIZATIONAL ENVIRONMENT

The organizational setting chosen as a basis for the live context study consists of a large, Chicago based corporation which produces and distributes a common consumer durable product in national and international markets. Annual sales volume exceeds $150,000,000 and the company continues to experience substantial growth, both through expanded markets and new product offerings.

The company's product line is relatively stable consisting of a single primary product and a small number of related products. Physical volume of the primary product exceeds 500,000 units per year. With minor exceptions involving institutional customers, the company relies on direct (door-to-door) sales techniques. This marketing strategy has resulted in the development of a large national sales force consisting of approximately 75,000 full and part-time representatives.

The company has led its industry both in product development and market penetration for a number of years. Not surprisingly, this industry position has supported, and perhaps resulted from, advanced management science applications, particularly in the data processing and information systems area. While it is difficult to meaningfully measure or categorize overall information systems development activities, the company's existing systems reflect the characteristics of an advanced management environment discussed in Chapter I.

The management by systems concept has been operationalized throughout the major processing and decision systems in the organization. Well developed systems groups, both in the planning and implementation dimensions, have worked over a period of years with outside consultants to develop and operationalize large-scale operating systems encompassing most of the firm's functional activities. Several of these computer-based systems have been largely integrated, sharing common data bases and serving interfunctional information requirements. Accordingly, a rather advanced degree of sophistication in systems processing activities including a well developed edit routine and input oriented coding structure has been achieved.

A large-scale customer profile data base has been established as an extension from the order processing system. This data base has been used to develop several advanced operations research applications in product development, marketing, and credit screening. A sophisticated, multiphase credit screen has been implemented as an integral part of the order processing system.

These and other aspects of the company's systems activities will be examined in some detail in subsequent sections. At this point let it be sufficient to suggest that the company's level of sophistication and experience with advanced systems applications qualified it as an advanced management environment relevant to the present study. While this type of environment is not commonplace at the current state of the art, it is clearly a very real environment and one which will be of increasing significance in the emerging generation of information systems technology.

This corporate environment is well suited to the current study in several respects. Beyond its advanced systems applications and established experience with computer-based systems technology, the company's management is highly systems oriented at a conceptual as well as technological level. Not only has the organization's system structure evolved to the point where high-level analysis inquiries are relevant, but also management is conceptually prepared and committed to pursue these inquiries effectively. Limited application of computer modeling and simulation techniques in an operations research context has provided management with an introduction to the methodology and its potential. Existing data bases and data collection mechanisms have provided an important, large-scale foundation for high-level analysis activities.

Finally, while this corporate context constitutes a significant real world organization both in terms of magnitude and systems complexity and sophistication, several characteristics of the company facilitate meaningful analysis within a manageably bounded study. The company's relatively homogeneous product line and marketing-distribution system avoid redundant complexities which would not contribute to the usefulness of the study.

Furthermore, since the company's operations consist primarily of product development, marketing and distribution, technical complexities underlying production activities will not be incorporated in the analysis. In reality, the company's products are produced by independent manufacturing firms unrelated to the corporate structure. The absence of a production dimension in the analysis does not inhibit evaluation of the methodology but avoids technical complexities which lie beyond the bounds of the study.

ORGANIZATION REVIEW AND CONCEPTUAL MODEL BUILDING

Through the organization review process, the analyst seeks to understand the dynamic interface of the organization's objectives and resources with its environment. This understanding requires an indepth inquiry into industry characteristics, market structure and legal and social contexts as well as a thorough investigation of company resources, policy specifications and operating characteristics. This process remains highly unstructured and must rely on effective, heuristic application of management experience and broad reference resources.

In the present context, the company under study markets a high marginal return product in national and international markets. Since the company's production activities are carried out through external suppliers, there is no effective constraint on production capacity. Accordingly, management is highly marketing oriented and views marketing activities as the primary determinant of company profitability on both a short and long-term basis. This management perspective is strongly reflected in policy specifications as well as the structure of existing operating systems.

Product sales are initiated almost entirely through the company's direct sales force. Accordingly, this large sales organization constitutes the company's primary link with the external environment. The sales force consists of some 75,000 full and part-time representatives. Seasonal factors lead to significant variations in the size of the sales force, resulting in as many as 100,000 representatives during high volume summer months. Sales representatives are compensated entirely on a commission basis. As the relative figures suggest, a large proportion of the representatives contribute little in sales productivity. A high turnover rate is experienced among these low productivity representatives.

The sales force is hierarchically organized with as many as ten levels of organization. In addition to the basic commission paid to the sales representative, as many as six levels of organization may participate in a complex overwrite, i.e., indirect commission, structure on each sale. Commission and overwrite payments constitute the single greatest element of operating cost, amounting to almost twice the cost of the product.

The sales organization is perceived to be an extremely significant company resource. The company's industry dominance and continued growth is attributed largely to efforts in establishing and managing the sales organization. Furthermore, a significant dimension of industry competition consists of recruiting and retaining effective sales representatives. Accordingly, the commission and overwrite structure may represent as important a competitive marketing variable as product price and terms.

Due to these considerations, management is highly marketing oriented and is particularly sensitive to any factors which may have an impact on the sales organization. This management perspective is manifested in a number of policy specifications which significantly influence the structure and operation of existing systems. The impact of these policy constraints is examined in relation to specific operating systems below. At this point it is important to recognize the basis and pervasiveness of this management orientation in order to appreciate the significance of systems relationships and interactions.

Approximately 80% of the company's sales are made on credit with extended time payment provisions. A typical contract requires a small down payment (approximately 5%) and monthly payments scheduled over

30 months. Accordingly, the management of accounts receivable is a major operation involving over 1,000,000 open accounts.

Credit evaluation and screening of incoming time payment sales is a major concern. The large volume and extended terms of time payment sales make the credit evaluation decision a significant determinant of total company profitability. For this reason, a major credit research project was initiated in 1960.

Working in conjunction with an outside consulting firm, the company's systems group determined that meaningful credit research required the development of a large scale, statistically valid data base encompassing customer profiles and credit experience. Since the relevant data required to develop an effective credit screen could not be fully anticipated, it was necessary to establish a broad sample record including many account characteristics of potential value in credit research.

The resources and time required to establish and maintain such a data base represented a major company commitment. The magnitude of this commitment required that a well planned system be implemented to achieve data base objectives. Since several years of data collection activities would be required to accomplish these objectives, inappropriate initial planning would be slow to emerge and very costly.

This planning phase revealed potential payoffs from the data base effort beyond the credit review area. Potential applications were identified in the rating of sales representatives to assist in hiring, training, and performance evaluation. Discriminant analysis could be used to structure more effective collection routines tailored to unique customer characteristics. Further statistical analysis could provide a basis for identifying high return market areas, customer groups, and sales promotion vehicles. Analysis of profitable customer characteristics could be used in product development and formulation of new product marketing strategies.

As a result of these considerations, the customer data base concept was substantially expanded. The design and implementation of the data base maintenance and data extraction systems required to support those objectives consumed several man years of outside consulting and internal systems group time. The resulting systems are highly automated and form an integral part of the order entry and transaction processing systems.

The data base system draws a random sample of approximately 4% from all new orders processed. The cumulative sample file currently contains data records for more than 100,000 accounts. A 600 character record is established for each sample account. The first 300 characters capture initial data when the order enters the system. The remaining 300 characters record transaction activity over the life of the account.

The initial data is drawn primarily from three sources. Account identification and terms information (approximately 16 items of data) is drawn directly from the order entry validation system as the new order is being processed. Detailed customer characteristics (over 20 items) must be coded manually from the customer application form and merged with the sample file. Finally, sales representatives information (four items) is drawn from the current sales organization file and merged.

The continuing transactions record includes data pertaining to payment experience, collection activities, service charges and performance of any outside collection agencies involved. Several record locations are available for special purpose applications as new or changing objectives and requirements are identified. Most of this data is automatically extracted from various transaction processing systems and merged with the sample file.

Sophisticated credit evaluation research based upon the experience accumulated in this data base has resulted in the development and implementation of an advanced credit screen system. A computer based screen derived from multiple characteristic, sequential discriminate models is incorporated in the order entry validation system. Credit applications rejected by this screen are reviewed further manually. The manual evaluation process draws upon outside sources of information including credit bureau files. Evaluation and interpretation of these inputs is based upon proprietary models developed through further credit research.

The data base system is further utilized on a continuing basis to validate and update the credit screen and related systems. As new data are accumulated in the sample file, they are analyzed to identify emerging trends or new relationships. The results of these analyses are tested for sensitivity in relation to existing programmed decision rules. When specified sensitivity threshholds are exceeded, the relevant systems are modified in accordance with the new experience or newly perceived patterns. This ability to monitor and react to changing environmental relationships within the ongoing information systems structure reflects a level of systems sophistication characteristic of an advanced management environment.

While implementation of the computer based credit screen system was demonstrated to represent a significant contribution in terms of company profitability, the possible impact of this system on the sales organization caused serious concern. Because of the commission structure, the sales representative is much more interested in sales than in collections or profits. Rejection of a potential credit sale may constitute a net savings to the company, but its immediate impact is a lost commission. Due to the volatility and the extreme importance of the sales representative, the ultimate impact of rejected sales is very difficult to assess. Indirect or intangible effects might easily exceed the direct impact of bad debt losses. Moreover, the execution of this "bread and butter" decision through an automated, computer based system was even more difficult to accept. Concern with these questions was a major factor in retaining the secondary manual review of computer screen rejected orders.

In order to minimize the negative impact of large numbers of credit rejections falling upon specific sales branches and in order to maintain dominant market penetration in all geographic areas, a policy of limiting the number of credit rejections for each sales branch per week was adopted. This credit rejection ceiling policy was implemented in the manual review system where credit decisions are accumulated for one week and reconciled with specific branch rejection ceiling percentages before any credit rejections are executed. As a result of this branch rejection ceiling reconciliation process, the company accepts numerous credit sales which would otherwise have been rejected by the two phase credit review system.

The credit rejection ceilings are derived through negotiation between sales branch management and home company management. The approximately 92 sales branches are partially independent from the home company. Sales branch profits derive primarily from overwrite payments while the home company manages the resulting accounts receivable to realize residual profits. As a result the home company and the sales branches pursue somewhat conflicting objectives.

This conflict in objectives is partially overcome through a "quality bonus" system which constitutes an incentive for branch management to produce high quality credit sales. A portion of overwrite payments on credit sales is withheld pending a minimum payout or "bonification" of the credit contract. When this minimum payout is verified, the withheld payments are released to branch management; otherwise, they are lost. While this system serves to lessen the discrepancy between sales branch and home company objectives, the magnitude of the withheld payments and the minimum payout terms are not restrictive enough to make these objectives congruent. The possibility of establishing a more potent quality bonus system is restricted by the volatility, semi-independence, and critical importance of the sales organization. As a result, some discrepancy in objectives persist and the negotiation of credit rejection ceilings remains a lively and difficult process.

This potential divergence of objectives is even more pronounced at the sales representative level. As indicated above, a substantial proportion of sales representatives are active with the company for a relatively short period of time and may produce few product sales before becoming inactive. This short period of association with the company is often not long enough to determine the payout on credit sales produced. Due to the perceived importance of maintaining a large sales organization and the active competition for additional sales representatives, the company has adopted a policy of commissioning credit sales when accepted. This immediate reward for sales effort is considered to be a significant incentive particularly for the marginal representative. As a result, by the time a serious credit default is discovered, it is often impossible to associate poor quality contracts with an active sales representative. Accordingly, the marginal representative is motivated to maximize sales, and therefore his commissions, rather than contribution to company profits.

More permanent sales representatives, who remain active with the company for a longer period of time, are subject to commission holdbacks if they consistently produce low quality business. When a specified frequency of default limit is exceeded on a given representative's sales, he may be classified as a substandard representative. A portion of the commissions earned by substandard representatives is withheld pending a minimum payout on their credit sales. Furthermore, credit sales generated by substandard representatives are always reviewed by the manual, second phase credit screen and these sales are not subject to the branch credit rejection ceilings.

As indicated above, management attaches great importance to the prompt rewarding of sales efforts both as an effective sales incentive and as an inducement to attract and retain marginal sales representatives. This perceived importance of associating effort and accomplishment or sales and commission payments within a short time frame is reflected in the structure and operation of the order processing and commissioning systems.

Sales commissions and overwrites are paid weekly. The 92 sales branches are divided into five approximately equal groups and each group is assigned a unique weekday as its payday. Accordingly, commissions are paid each weekday, on a revolving basis, to approximately one-fifth of the sales organization. A commissioning cutoff has been established which specifies that all orders received from a given branch by the last mail delivery two days before the branch's payday will be commissioned or otherwise disposed of by that payday. This policy is intended to assure uniformly prompt commissioning of all sales.

The implementation of this policy imposes a number of significant constraints on the order processing and credit review systems. Orders received in the home office near the cutoff of a pay cycle must clear the entire order processing system, including the two phase credit screen in less than one working day in order to be commissioned on time. This requirement causes severe resource budgeting problems throughout the sequential operating systems (discussed below) which carry out the order entry and credit review functions. These problems can be conceptualized as a complex, stochastic queueing system which is prone to significant resource imbalances and bottlenecks causing processing delays.

In order to assure that the prompt commissioning policy will be realized despite order processing problems, a corollary policy has been established which specifies that any orders awaiting credit action when the last system processing cycle is executed on the day before payday (at approximately 6:00 p.m.) will be automatically accepted and commissioned. The only exception to this policy are that orders generated by substandard representatives and orders with a special branch request for credit review can be held past the deadline and processed in the next payweek. Particularly during high volume periods, this policy can result in the automatic accepting of significant numbers of orders which would otherwise have been rejected by the two phase credit screen. Given the high reliability of the credit screening systems, this implies an increase in collection and bad debt expenses and a reduction in profits.

These time phase relationships are summarized in Exhibit 5-1 which is based on a Thursday or payday #4 pay cycle as an example. The deadlines for major orders processing and commissioning events are presented for payday #4 orders; the sequence for the other four pay cycles is identical, but shifted appropriately on the time line. The processing operations referred to are analyzed in a subsequent section of this chapter.

EXHIBIT 5.1

REVOLVING PAYDAY SYSTEM: PAYDAY #4

MONDAY:	New order contracts submitted by sales representatives during preceding week mailed from sales branch to home office.
TUESDAY:	Cashiering order processing cutoff at 4:45 p.m. Last mail received at 3:00 p.m. Editing order processing cutoff at 4:45 p.m.
WEDNESDAY:	Last computer-based processing system validation sequence: Midnight: 80 to 90 percent of new orders released to Terms and Credit Review. Noon: 80 to 90 percent of resubmitted orders released to Terms and Credit Review. 6:00 p.m.: Terms and Credit Review decisions executed and accepted orders released to Payroll. Credit Review order processing cutoff at 4:45 p.m. with final disposition orders executed in 6:00 p.m. validation run.
THURSDAY:	Payroll issues and mails commission and overwrite payments to sales branches.
FRIDAY:	Commissions received at sales branches and distributed to sales representatives.

The revolving payday system was designed to level order processing and commissioning requirements across the workweek. Due to the volatility of the sales organization, with constant changes in the size and structure of sales branches, the assignment of sales branch paydays to accomplish this objective is a complex persistent problem. The difficulty of this problem is increased by the varying behavior of specific sales branches in timing the submission of orders to the home office.

Analysis of order submission distributions by specific sales branches across their payweek reveals a number of distinct patterns. The data and analysis underlying these conclusions are discussed in Chapter VI, below. The major finding of this analysis is that many sales branches choose to submit their accumulated orders for a payweek in one batch immediately before the cutoff for the payweek. This action imposes severe time constraints on the processing, credit review and commissioning of these orders before the payday deadline. As a result, the probability of having to accept credit sales without review is substantially increased. Furthermore, the budgeting of resource requirements to reduce this probability is made more complex and less efficient.

Several possible reasons for this behavior can be identified. In some cases the office staff at a sales branch consists of part time people who are available for order submission only at the end of the payweek. In some cases sales representatives work some distance from the branch office and report in only to submit orders at the end of the week. Nevertheless, the possibility has been recognized that some branch managements or individual sales representatives may intentionally withhold orders until the end of their payweek to maximize the probability that poor credit risks will have to be accepted without review. This action would be consistent with their objective of maximizing commissions and overwrite payments rather than residual profits.

While the company strongly encourages immediate submission of orders, this encouragement has not resulted in uniform compliance. The semi-independent status of the sales branch together with the perceived importance of attracting and retaining sales representatives has prevented stronger action in this regard. A comprehensive system model capable of evaluating the impact of alternatives is required to establish an operational basis for top management decisions in this area.

The complexity and significance of these order processing relationships and policy constraints are increased by the structure and magnitude of the sales organization. Even minor changes in systems and policy specifications may involve rather large dollar amounts. Moreover, the interdependencies among systems relationships together with the necessity to consider perceived constraints which cannot be readily quantified produce a system context which cannot be meaningfully analyzed through intuition or packaged analytic models. The specific operating characteristics of this system context are examined in the next section in order to form a basis for developing the operational system model required to support the high-level analysis process.

ANALYSIS OF OPERATING SYSTEMS

The objective of this section is to relate the general overview of system relationships set forth above to specific operating systems and policies in the ongoing organization. This analysis of existing systems constitutes a concrete representation of systems relationships as well as a conceptual structure for the computer-based modeling effort. The analysis process provides a vehicle for integrating and structuring diverse management experience and perceptions in a common framework with explicitly specified relationships, constraints and assumptions. This common framework will constitute a conceptual blueprint for the operational systems model required for the high-level analysis.

In this context, analysis of the primary operating systems can be systematically structured to correspond to the information flows which constitute the new order entry and credit review processes. Other supporting systems will be related to these primary information flows. This structure of analysis provides a systematic framework for examining the interactions among related subsystems and also provides a convenient physical structure for the analysis process. As a result, the analysis of information flows can be tangibly verified and documented with physical work flows, communication networks, organizational relationships, and document flows. The macro structure of these primary information flows is summarized in the systems flow chart presented in Exhibit 5.2. The following discussion elaborates on the relationships depicted in the flow chart.

New orders are origginated by the sales representative through direct contact with the ultimate consumer. At the point of sale, the representative and the customer execute a purchase contract including an installment credit agreement if appropriate. The purchase contract

EXHIBIT 5.2

MACRO-CONCEPTUAL FLOW CHART OF NEW ORDER PROCESSING SYSTEM

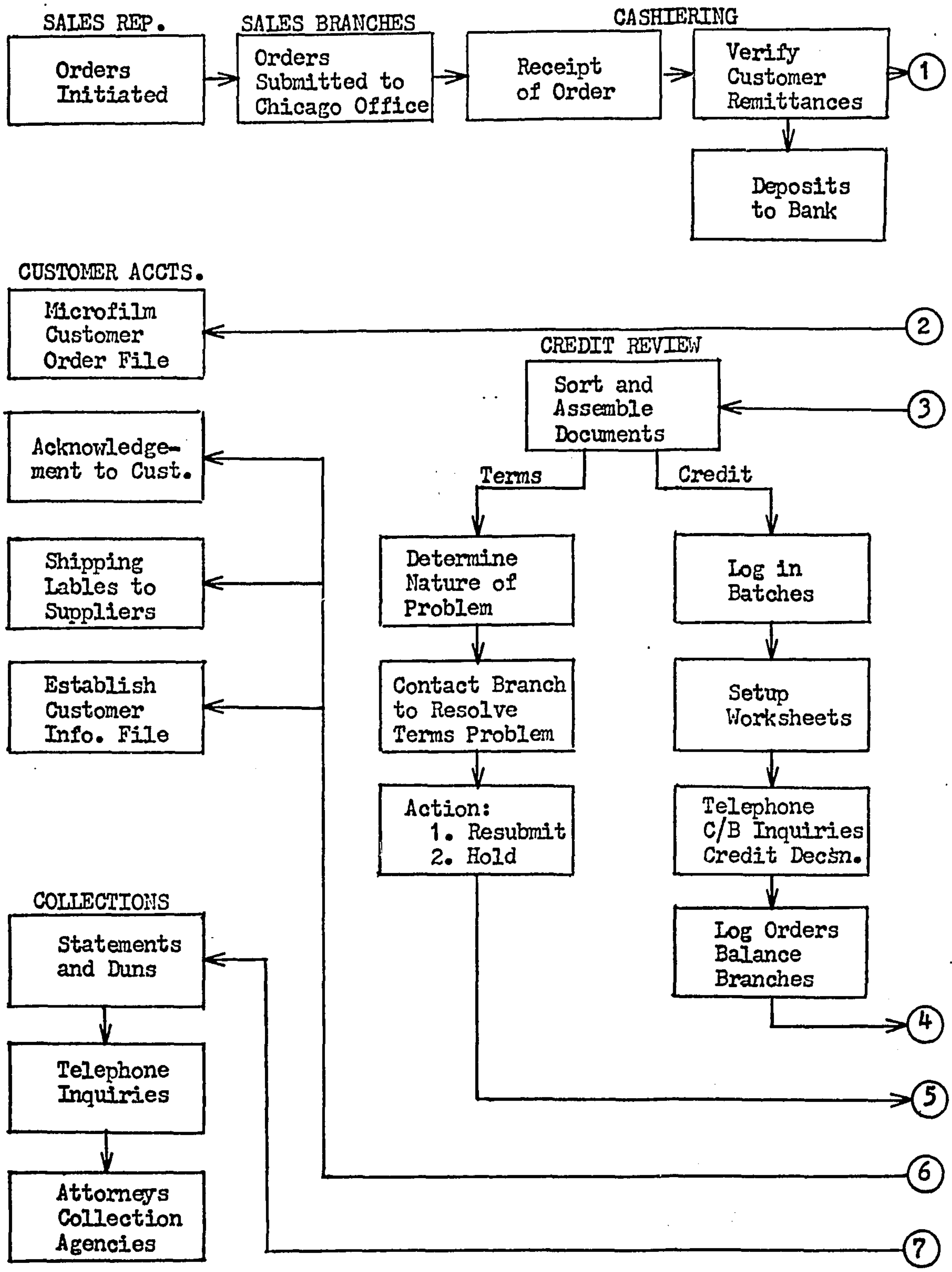
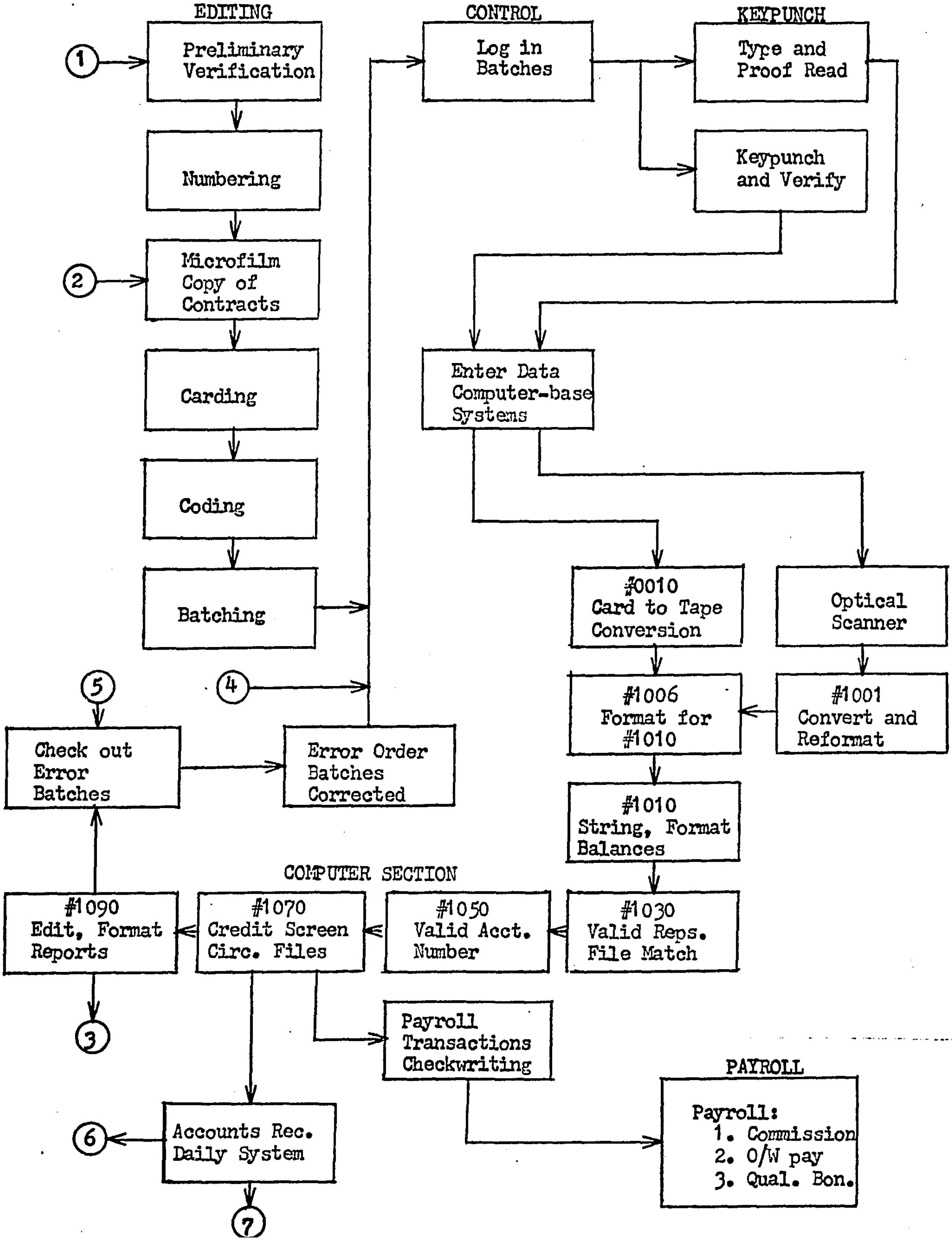


EXHIBIT 5.2 (Continued)



specifies the product(s), prices, and payment terms; identifies relevant sales organization relationships, and captures credit review data supplied by the customer. Ordinarily a minimum down payment is required to be submitted with the purchase contract.

The sales representative submits these purchase contracts and down-payment remittances to his sales branch office. The delay between execution of the contract and submission to the branch office is neither uniform nor negligible. The impact of this delay is examined in Chapter VI.

Each of the approximately 92 sales branches submits accumulated purchase contracts to the home office at least once every week. Again, the accumulation procedures and delays involved are a matter of concern and are examined below. Control is established for all orders submitted to the home office through a sales summary document. Because of the revolving commissioning system, the date that orders are submitted is critical and is closely monitored.

New orders are received by the home office in the cashiering department. Mail pickups are scheduled almost hourly from 7:00 a.m. to 3:00 p.m. each weekday. The cashiering department "strips" all remittances and establishes a cash control. Remittances are sorted among appropriate accounts differentiating payments on accounts receivable from new order down-payments and sorting across major sales divisions. New order contracts are batched for convenient handling and forwarded to the order editing department on a "when processed" basis throughout the day. Cashiering closes at 4:45 p.m. after which no new orders are accepted by editing.

By policy, any orders received by the second day before a branch payday must be commissioned on that payday. Accordingly, the timing of order receipts is critical and is verified by a time stamp in cashiering. Due to time constraints in processing "critical" orders, it is essential that all mail receipts clear cashiering each day. This policy, in conjunction with extreme volume variations across the year, creates a difficult resource budgeting problem in cashiering. The work force required to process the minimum order flows of a few hundred per day can not begin to handle the maximum flows of several thousands per day. This situation has resulted in some over staffing and frequent use of part-time people borrowed from other departments or acquired from the outside. As a result, cashiering experiences frequent training and inefficiency problems during high volume periods.

The order editing department basically prepares the new order contracts for entry into the computer-based systems. Orders are reviewed for complete and consistent information to the extent possible. A more thorough "validation" of order data is carried out through an editing routine incorporated in the computer-based system; however, errors discovered at this point may be difficult to correct before the commissioning deadline.

Each order is assigned a unique account number which will form the basis for all subsequent processing and accounting transactions. The numbered order is then microfilmed for a customer accounts file. This file provides a manually accessible data base to service customer inquiries and other contract problems.

At this point orders are sorted by payday and coupled with a color coded punch card indicating the pay cycle. Particularly during high volume periods, it is essential to process the most imminent pay cycle orders first in order to satisfy the commissioning policy without sacrificing the credit review. While the formal processing policy in editing is first in, first out, selective processing is often necessary. Even at moderate volume, this procedure may be deemed desirable in order to provide maximum flexibility in meeting subsequent processing deadlines.

The major operation in editing consists of transferring pertinent information from the purchase contract to a highly condensed coding form which is formatted to be compatible with the computer-based systems data requirements. This coding operation involves the translation of numerous "descriptive data" to specified numeric codes. The translation process is quite complex and requires operators with considerable training and experience.

The completed coding forms are accumulated into batches of 25 or 50 orders for control purposes. These batches are then forwarded to the keypunch area where they are prepared for computer entry.

The editing department is staffed to process approximately 2,000 orders per day efficiently. When new order volume falls below 1,500 per day, idle time results and the average processing cost per order becomes excessive. Seven thousand orders per day is considered to be the maximum capacity of the department. Volume at or above this level creates significant organizational strain and results in processing delays and errors. Unlike cashiering, the editing department is not able to absorb excess volume through the use of part time or temporary labor due to training and experience requirements. As a result, substantial overtime premiums are often incurred during high volume periods.

These characteristics of the editing operation in conjunction with the commissioning deadline policy create significant resources budgeting problems in the context of high volume variations. The potential for interdepartmental conflicts involving the timing of work flows is evident and, is in fact, a reality. The interdependencies among various processing departments are often critical and difficult to isolate in terms of cause and effect.

Batched orders received in the keypunch area may be prepared for computer entry by two methods. The best established and most reliable method involves conventional keypunch and verification operations. A substantial crew of experienced keypunch operators is maintained for this purpose. The keypunch operators require considerable experience with the order coding form and established format specifications to work efficiently. Accordingly, the keypunch area experiences resource budgeting problems similar to those experienced in editing.

In order to circumvent these problems and provide an alternative to conventional keypunch processing, an optical scanning facility has been established. While other special purpose scanning applications including the processing of payments on accounts receivable and direct mail transactions are well established in the company, this application requires extended capabilities due to the quantity and diversity of data to be captured. The scanner is capable of reading a special typed copy of the master coding form which it transfers directly to computer media. The typed copy is prepared in a manner very similar to conventional typing. As a result, operators from the company's office typing pool can be utilized to prepare input for the scanner during high volume periods with little special training or experience. This method has quite successful to date; however, reliability problems with the scanner system have compelled retention of the conventional keypunch capability as the primary processing mode. Cost comparisons between the two systems are not entirely clear and are still under study.

Batches of new orders, keypunched or typed and scanned, are forwarded to the computer area for entry into the computer-based systems. Computer operations are executed entirely on a batch processing basis. Several medium-scale computers and extensive tabulating facilities are utilized simultaneously for this purpose.

The new order processing system which includes numerous subsystems is run three times daily. Run times are scheduled for 12:00 midnight, 12:00 noon and 6 p.m. While there is some flexibility in this schedule, the size and complexity of the computer-based system prohibit significant delays. The scheduling routine is crucial both to complete required processing operations on limited computer facilities and to maintain appropriate time phasing with other clerical and managerial activities which are closely linked to the computer-based system. These time phase interdependencies among computer-based and manual operations represent significant constraints to the work flow in new order processing.

The primary computer-based system is highly sophisticated and encompasses numerous information flows and processing functions. A macro flowchart of the primary system is presented in Exhibit 5.3 to illustrate the scope and structure of computer-based operations.

EXHIBIT 5.3

MACRO FLOW CHART OF COMPUTER-BASED PROCESSING SYSTEMS

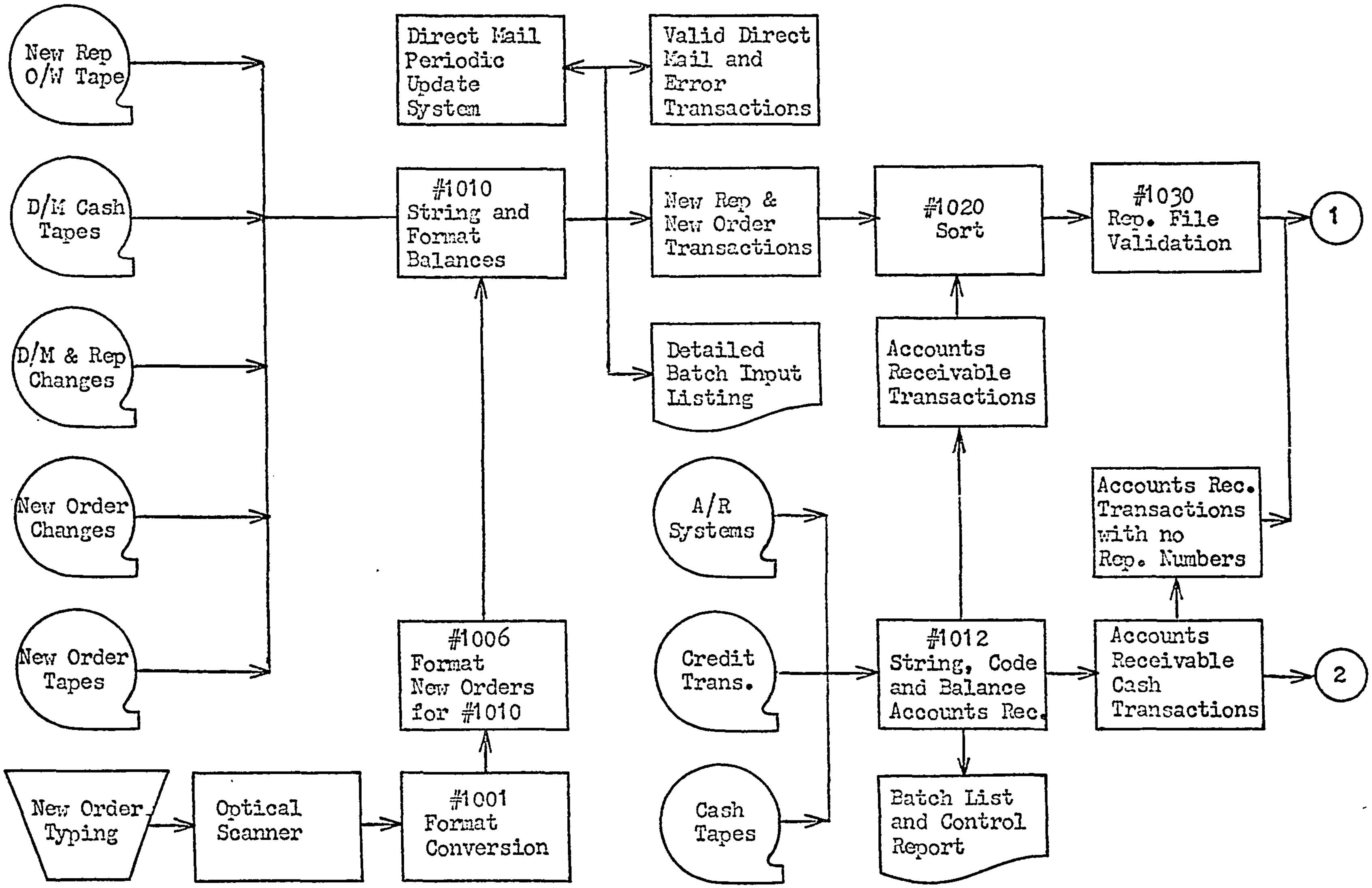


EXHIBIT 5.3 (Continued)

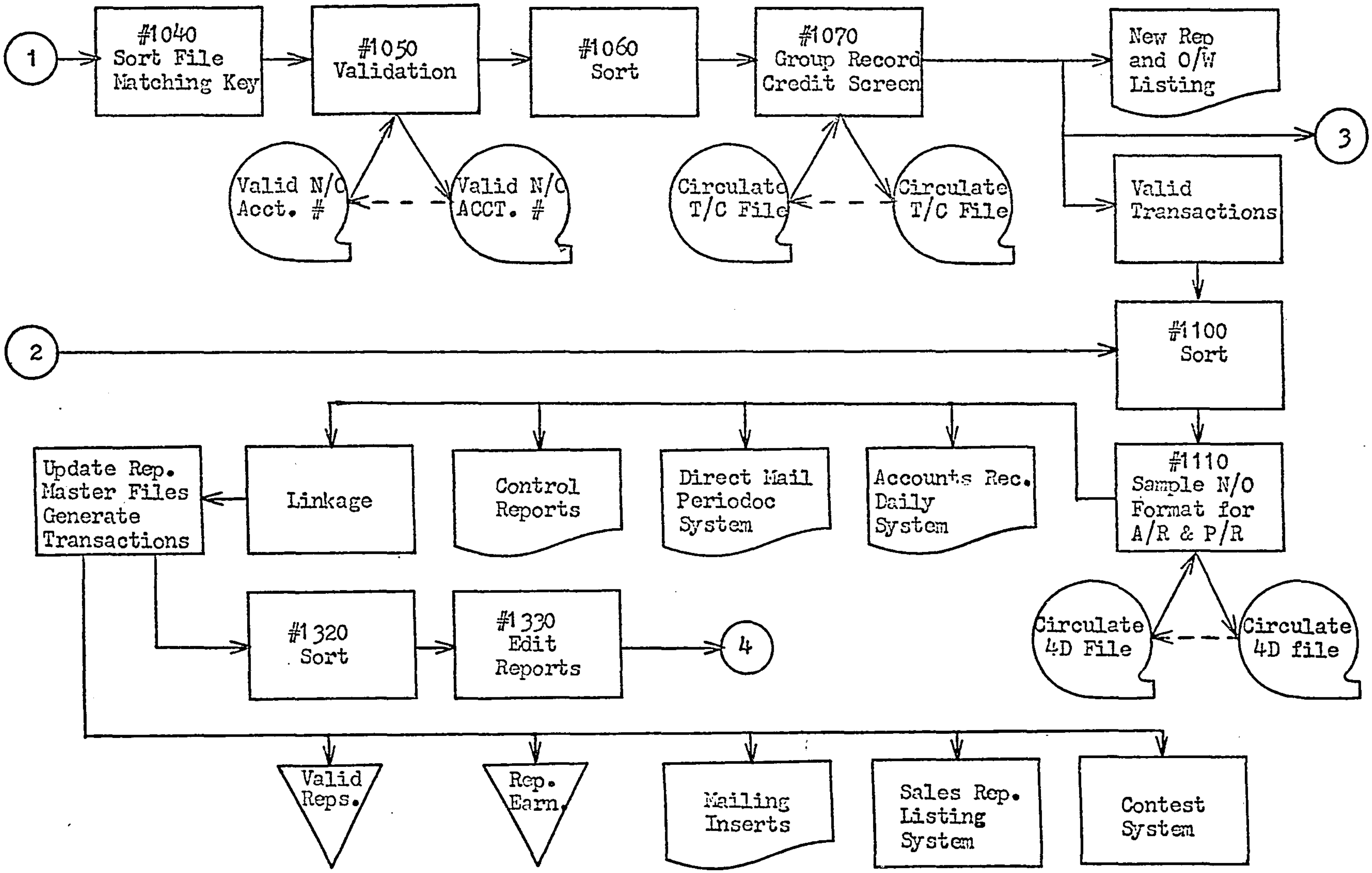
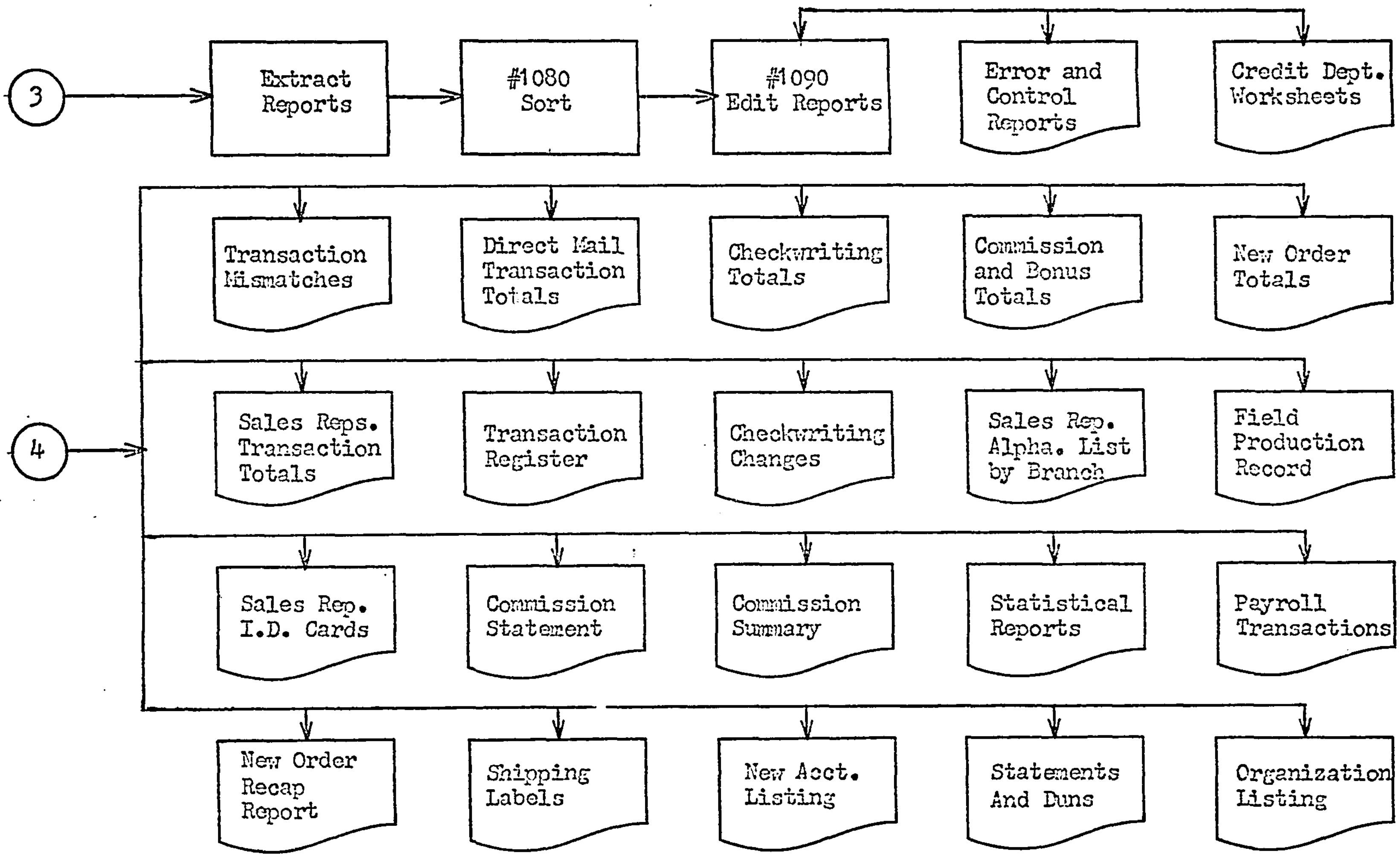


EXHIBIT 5.3 (Continued)



Selected elements of this sytem which are particularly relevant to the high level analysis are discussed in the following paragraphs.

An essential function of the computer-based system is the "validation" of new contract information summarized in the master coding form prepared by the editing department. From an information system standpoint, this validation process constitutes an edit routine which analyses transaction data in terms of the comprehensive coding structure underlying the company's operating and information systems. This essential systems function is a prerequisite to multi-dimensional, integrated information systems activities which characterize an advanced management environment.

From another perspective, the edit routine constitutes the core of an advanced systems processing function which operates on common data for a number of data bases and files maintained both on and off-line to the computer-based systems. The completed customer purchase contract represents a comprehensive input oriented unit form which captures data relevant to several operating systems simultaneously. The systems processing function verifies, sorts, and stores these diverse data inputs in accordance with the requirements of these various operating systems. By this means, the customer information file, credit research sample, shipping instruction file, accounts receivable ledger, customer acknowledgment file, commission summary files and numerous other data files are generated from the coded sales contract in accordance with the unique data requirements, processing time frames and data file structure requirements of the various operating systems.

In addition, the systems processing capability encompasses other inputs to the computer-based systems. Collections experience relating to the credit sample file discussed above, sales productivity statistics, credit bureau information and other relevant inputs are appropriately verified, sorted and merged with the related common data bases. Furthermore, large quantities of data not specifically required by existing operating systems, such as credit discrimination variables associated with contracts not selected for the credit sample, are stored off-line on micro-film files for possible future requirements.

Among the functions of the validation process are the verification of items sold, pricing, terms of payment, identification of sales organization involved and preliminary transaction analysis. Any irregularities or ambiguities identified through this process initiate an appropriate error report addressed to the organizational unit responsible for correcting or investigating the problem. The most common problems dealt with involve contract inaccuracies, coding errors and keypunch or scanner errors. These problems are diagnosed, listed and referred to the editing department for correction. After analysis and correction, the editing department resubmits the coded contract to the next computer runs.

It is important to note the impact of this error, correction and resubmission process. While total error conditions seldom exceed 10% of orders submitted, their efficient handling is crucial to the viability of the system. Since an improportionate quantity of orders are received at or near the cut off for a given pay cycle, any delays due to error correction loops vastly increase the probability of credit review and commissioning policy conflicts. The cut off in editing for new orders in a given pay cycle is 4:45 p.m. two days before payday. All orders must clear credit review by 4:45 p.m. one day before payday. If near cut off orders are submitted to the computer-based system by the midnight run on payday minus two, credit review has one work day to review these orders. If an error condition is found, the correction will generally be submitted by the noon run on payday minus one, and credit review may have less than two hours (or no time for east coast orders) to complete the review process. Accordingly, error orders are most likely to require automatic acceptance at the credit review cut-off and, of course, are not ordinarily the highest quality orders. This relationship serves to increase the difficulty of resource budgeting decisions in editing and other processing departments.

Other error conditions involving inadequate down payments or unacceptable terms are listed, coupled with the original contract and forwarded to the terms department. Terms problems are investigated by a phone crew or by mail and may take some time to resolve. These contracts are specifically exempted from the commissioning cut off policy and can be held until the investigation is complete.

When a new time payment contract passes the edit routine, it is evaluated by the computer-based credit screen to predict contract payout. Contracts with a "quality index" below a specified cut off point together with substandard representative and branch request contracts are listed and referred to the credit review area for a secondary manual evaluation.

The credit review listing is coupled with the original contracts, the related master coding forms and computer produced worksheets. These documents are forwarded to the credit review department where they are sorted by pay cycle and logged in for control. The credit review supervisor enters an appropriate local credit bureau telephone number on each credit worksheet and distributes matching contracts and worksheets to a crew of credit evaluators working with long distance telephone facilities. The credit evaluator contacts the local credit bureau, obtains a credit report and makes an accept/reject decision on the basis of a complex set of semi-heuristic criteria. The completed worksheets are logged in and accumulated until the end of the pay cycle when credit decisions are balanced against credit rejection ceiling specifications. Final disposition orders must be submitted to the computer-based system by the 6:00 p.m. run on payday minus one to be executed. Any orders pending credit action and not specifically rejected at that time are automatically accepted by the computer system during that run.

Work flows in the terms and credit review departments are summarized in Exhibit 5.4 These departments are related through shared physical facilities and numerous information flow interactions due to the correlation between terms and credit problems.

Resource budgeting problems are severe in the credit review area

EXHIBIT 5.4

ORDER PROCESSING IN TERMS AND CREDIT REVIEW AREAS

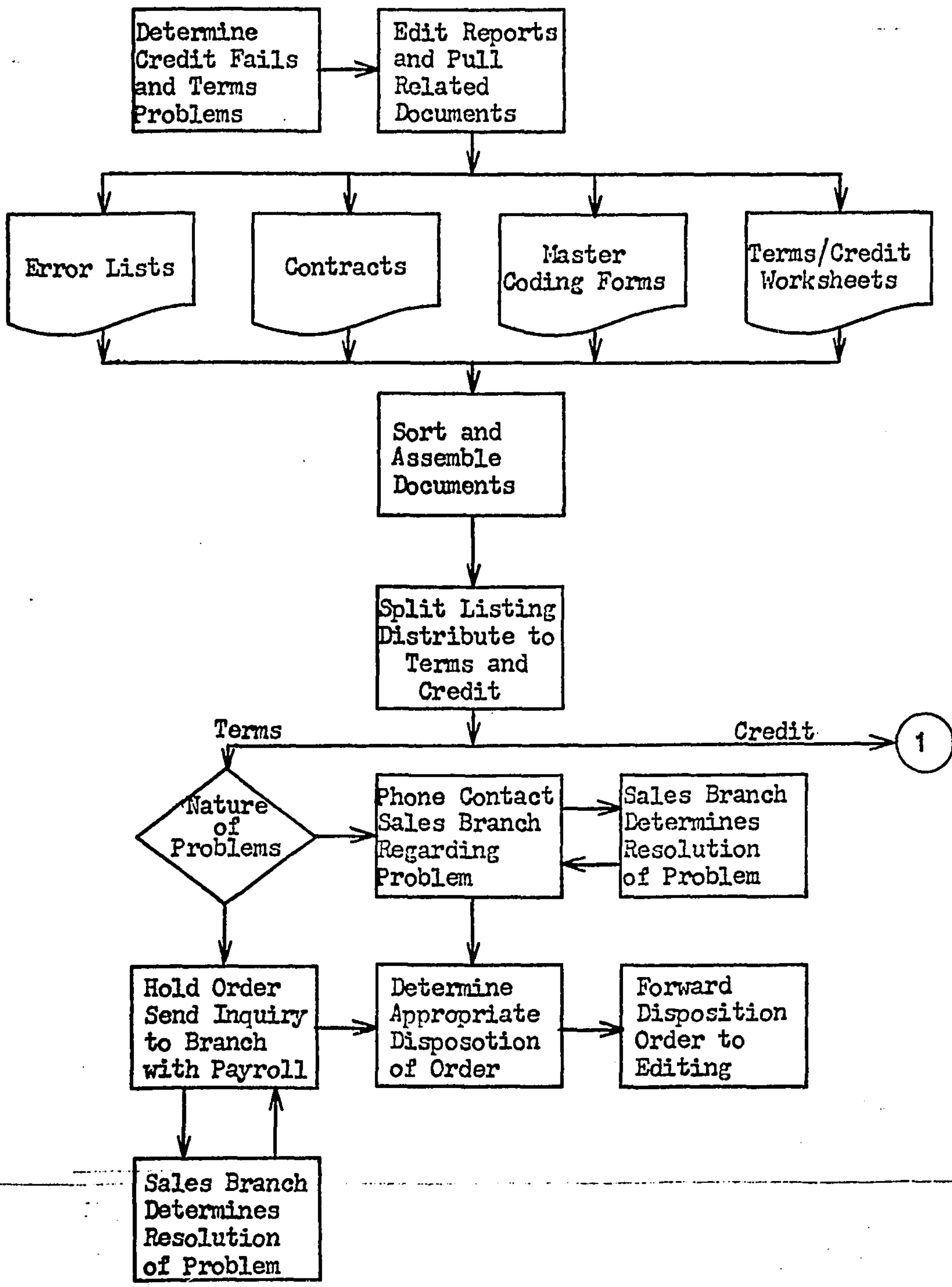
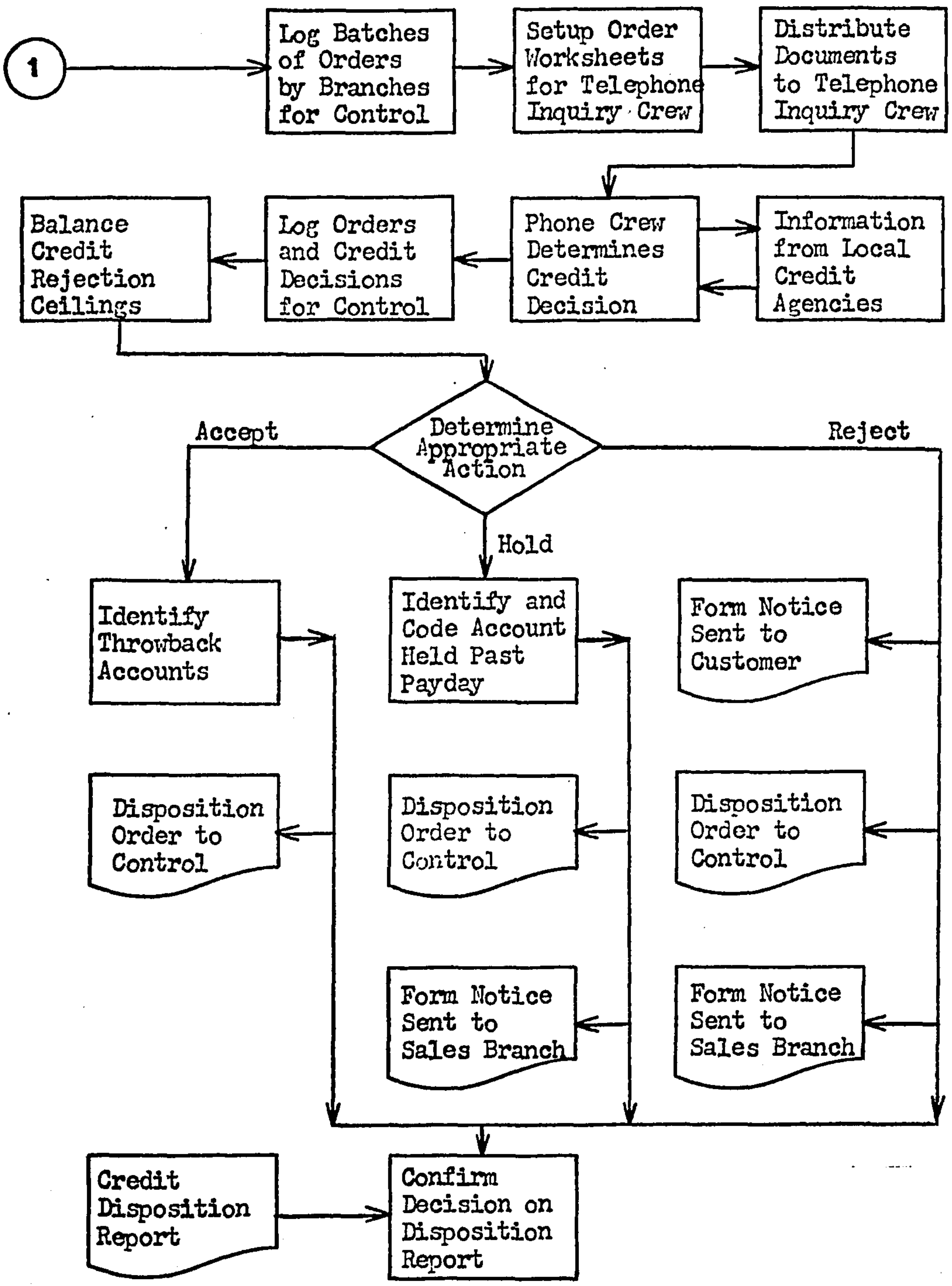


EXHIBIT 5.4

(Continued)



where the final processing deadline must be met, and trained, experienced personnel are required. Any delays, feedbacks or bottlenecks in previous processing operations are ultimately felt in credit review. Resource budgeting and quality control decisions made in other processing departments have a cumulative impact in credit review and, accordingly, affect the quality and cost of credit decisions.

Volume variations in credit review range from a few hundred to a few thousand orders per day. In order to absorb these variations, some personnel in the collections department are trained for credit evaluation and are called upon during high volume periods. Nevertheless, extremely high volume may necessitate mass acceptance of orders without review or with highly abbreviated, unreliable review. The cost of these decisions is being studied by means of a special sample of these accounts.

When an order has been accepted, the primary computer-based system establishes an accounts receivable file, prepares an acknowledgement for the customer, creates a customer information file and prepares a shipping label for the supplier who ships the product directly to the customer. In the course of this process, the computer-based system generates numerous statistical and control reports for management throughout the organization. A few of these reports including invoice statements, customer acknowledgments and shipping labels, are identified in Exhibit 5.3 above.

At the end of each revolving pay cycle, the computer-based system calculates commission and overwrite payments earned during the preceding week for approximately one-fifth of the sales organization.

This information is coupled with computer generated reports on quality bonus payments, commission and overwrite holdbacks and drawing accounts and is forwarded to the payroll department. Due to the size, volitility and complexity of the sales organization, the payroll function is unusually complex. However, the computer-based systems provide adequate support for the effective execution of this function despite volume variations and commissioning deadlines.

In the course of processing payments on accounts receivable over the life of time payment contracts, the computer-based system generates extensive information-flows to support collection activities. A sophisticated hierarchy of collection procedures including multiphase programs of written notices, telephone inquiries and collection agencies is controlled and monitored by computer based systems.

Statistical models which measure the cost and effectiveness of alternative collection programs are incorporated as an integral part of these systems. Automated random and matched sampling procedure are employed to build statistical data bases required to evaluate collection activities and forecast cash flow relationships.

The magnitude and sophistication of these activities make the collections function a major operating system of the company. At an operations level this system interacts with credit review activities through semi-shared facilities and personnel. As noted above, collections personnel may be called upon to assist in credit review functions during high volume or bottleneck processing periods. This relationship potentially causes resource budgeting and performance measurement problems for collections as well as credit review.

At a more fundamental level, credit review and collections activities are closely interrelated by their essential input/output relationship. Inadequate performance in credit review produces more and more difficult work in collections on a lagged basis. Inabilities to process large volume of orders in credit review which result in mass acceptance at the commissioning cut-off can be traced to increased collection problems in succeeding months. Of course, these relationships extend beyond the credit review and collections areas. Sales branch delays in submitting orders, processing delays in order editing and excessive order error conditions requiring reprocessing all contribute to complex volume variations in credit review which result in collections problems.

SUMMARY

The systems activities and relationships described above are summarized in the macro conceptual flow chart presented in Exhibit 5.2 This description has necessarily been a rather coarse representation of a complex, highly involved system. The systems analysis summarized here required over 18 months of on and off site investigation including detailed analysis of systems relationships and implications.

The investigation was initiated from the office of the Vice-President of Administration and enlisted broad management participation throughout the organization. Systems activities involving significant processing operations were physically observed in detail. Interviews with operating personnel were used as a basis for conceptualizing systems activities and flow charting physical and information flows. These representations were then reviewed with supervisory management to verify their accuracy and completeness and to explore inter system relationships. Interdependencies among subsystems and total system relationships were documented and verified with the company's systems planning and evaluation group. Finally the overall conceptualization was reviewed with upper management and outside consultants having extensive experience with the company.

The broad systems relationships summarized in the macro conceptual flowchart constitute a rather complex sequential queueing system with numerous interdependencies, feedbacks, and constraints. Time phase relationships among sequential subsystems are crucial and involve significant dollar impacts. Potential conflicts among various subsystem objectives, resources and constraints are obvious, but their implications for total system performance are not clear. The immediate impact of operating policies, constraints and performance measures within specific subsystems may bear little relation to the impact on the total system through involved interactions and interdependencies.

Even this brief review of system characteristics and relationships suggests a number of significant inquiries and potential alternatives. At this point in the analysis process, these implications are highly preliminary; but consistent with the heuristic nature of the high-level analysis, they are worthy of note and will influence the structure of the operational systems model.

Among these potential inquiries is the impact of shifting specific sales branches among pay cycles. Can a better balancing of order flow both in terms of expected values and extremes be achieved by this method? If the pay cycle concept and related commissioning deadline policies were abandoned, what would be the impact in terms of processing efficiencies, collections experience, and time distribution of commission payments? What would be the effect on work flow variations of moving back the order submission deadline by one or two or three days? What is the value to the total system of a lower error rate or higher processing rate in editing or cashiering or keypunch? Would a more costly system of direct entry of order information through remote computer terminals be justified in terms of reduced errors and faster data entry? Would more frequent batch processing or real time processing of orders when received significantly reduce work flow bottlenecks and volume variations? What would be the total impact of eliminating the manual credit review or the credit rejection ceilings?

These questions are a small sampling of the inquiries immediately implied by the preliminary systems analysis. Other dimensions of the analysis are discussed further in subsequent chapters. The essential observation at this point is that meaningful analysis of questions like these requires an operational system model capable of measuring the impact of specified decision and policy variables with complex interactions and interdependencies involving large segments of the total system. Local analytic models within operating subsystems cannot satisfy these information requirements. At this level of analysis, interactions among related subsystems are more significant than local subsystem optimization in terms of total system performance. Furthermore, the extent and complexity of these interactions in general renders conventional analytic models intractable or unspecifiable.

Neither does the conventional accounting "information system" model provide for the required information flows. Much of the content of these information requirements is not ordinarily incorporated in a conventional accounting system. Moreover, the conventional accounting model is built around coding structures or classification schemes which are defined in terms of independent, separable entities unrelated to the present analysis requirements.

These requirements necessitate an operational systems model defined in terms of the conceptual model developed through the systems analysis process. The operational system model is defined by the same analysis process which identified significant decision areas and resulting information requirements. Indeed, definition of the system model and identification of decision information requirements are but two aspects of the same process; each is logically implied by the other.

The operationalization of the system model requires a relevant data base and a methodology for representing system relationships in operational form. In the present context, this process consists of translating conceptual systems relationships to computer-based program interactions and operationalizing the resulting simulator with appropriate data. Significant elements of these data and operational modeling requirements are discussed in Chapter VI below.

While Chapter VI is addressed primarily to the methodology of computer-based systems modeling, the application of the methodology to specific measurement problems is discussed in Chapter VII. In this context, a number of measurement applications including the preliminary inquires identified above are developed in terms of a framework including (1) resource requirements, (2) capital budgeting, (3) system design alternatives, (4) decision criteria and (5) policy alternatives as well as potential modeling and operationalization extensions to the computer-based analysis process. In addition, a number of subsidiary or spin off applications from the high level analysis process are discussed in Chapter VI including a significant resource allocation problem in the telephone communication area which is developed both in terms of the relevant system context and selected simulator output. While these application areas are intended to be illustrative in character, they do constitute a representative sampling of the nature and range of simulation based measurement encompassed within the high level analysis process.

VI. OPERATIONAL APPLICATION OF HIGH-LEVEL ANALYSIS

Operationalization of the conceptual system model constitutes a process of translating verbally or conceptually articulated systems relationships into a formally specified and structured framework. This process parallels the process of formal definition in a linguistic or mathematical context. Interrelated concepts and relationships must be specified explicitly and completely. Logical gaps, inconsistencies and ambiguities are powerfully highlighted in a formal framework which must stand alone and bear examination.

Operationalization of the system model is a heuristic, iterative process. As emphasized in preceding chapters, the analysis process seeks to comprehend systems relationships in a dynamic environment. Accordingly, the system model must be adaptive over time. Furthermore, the modeling process is heuristic at any given point in time, adapting to specific information requirements and perceived problems. Simulation based measurements and sensitivity testing of model parameters and inputs may suggest new data requirements and model modifications and extensions as the analysis process is pursued. In fact, this identification of high sensitivity or high payoff elements of the system model represents a significant dimension of the high level analysis process.

The formal modeling process is an instrumental step in the high level analysis; however, significant immediate benefits may be realized. The formal specification of systems relationships in operational terms often reveals inconsistencies, suboptimalities or significant alternatives which were not previously evident. Conflicting policies and inappropriate informal procedures can become established over time with no explicit recognition. The formal modeling effort represents a structured opportunity to discover, investigate and modify these situations.

Comprehensive system modeling within a common, rigorous framework also provides an effective communication vehicle among management groups and between management and the systems group. Conflicting subsystem objectives or performance measures and the impact of subsystem interactions can be explicitly identified and evaluated within the context of the system model. The common language of flowcharts, parameter specifications and data inputs constitute a uniform, understandable representation of system relationships and a basis for mutual discussion and understanding.

The operationalization of the conceptual system model as a computer based simulator requires extensive data gathering and analysis and major computer oriented systems analysis and programming efforts. Significant dimensions of these requirements are discussed in the following sections. This discussion is related to problems and insights encountered in the field study introduced above.

NATURE OF DATA REQUIREMENTS

Formal specification of the computer based system model and establishment of the data base required to support implementation of the model are closely related processes. Neither activity is independent of the other and, in fact, an iterative approach pursuing both objectives simultaneously is required. Preliminary data analysis activities may provide insights which will influence the design of the model; yet, at the same time, data base requirements cannot be fully defined until the formal model is specified. For the purpose of this discussion, selected aspects of the data base problem will be considered first, followed by a discussion of the computer based modeling process. However, it is understood that these areas are highly interdependent both at a conceptual level and in terms of the time phasing of the high level analysis process.

Data requirements for the operational system model extend beyond conventional financial and monetary measures. As outlined above, the system model is concerned with physical systems relationships involving materials, personnel, productive facilities and information as well as financial resources. Moreover, the required measurements must be defined in terms of the relevant systems relationships rather than arbitrary frameworks or coding structures intended for other purposes.

In the context of the field study introduced above, essential data requirements for the operational system model will include order entry distributions for each sales branch, both computer based and manual credit review experience for each branch, processing and error rates in each processing department, distributions of order delays by queue and by cause as well as detailed specification of operating policies and time phased sequential processing relationships. Even this abbreviated list suggests that data sources must be established beyond the conventional accounting and record keeping systems. Much of the required information involves highly disaggregated data in the form of frequency distributions and time phase related measurements. In general, conventional accounting orienting record keeping systems are neither intended nor capable of providing this data. Not only are these data requirements highly diverse and rather unique in the context of conventional record keeping systems, they are also massive in scope and sheer quantity. Without doubt, this factor alone has precluded more active efforts in this area. The resource commitments required to establish an adequate data base for the high level analysis are significant, both in terms of cost and time. It is only in the context of an advanced management environment that these constraints realistically can be overcome.

Moreover, just as the operational system model must evolve in response to changing information requirements, the data base required to support the system model must be heuristically redefined and updated over time. As significant systems alternatives are evaluated and new avenues of inquiry are perceived, the supporting data base must be refined and extended. Initially gross systems relationships may be investigated with a limited data base, but as specific applications are pursued and iterative sensitivity testing reveals the need for more precision in specified areas, related data requirements must be more precisely defined and expanded in scope. Again, the process of data specification is never complete, but rather the data base must evolve with the analysis in response to new perceived problems and alternatives.

DATA ACQUISITION

As indicated above, data base requirements must be defined in relation to the system model and specific information requirements. As the system model is heuristically modified and extended over time, the data base system must be capable of responding to new and changing requirements. While the initial data base required for a preliminary analysis may be easily manageable in scope and complexity, as the high level analysis progresses data acquisition and maintenance become major problem areas. Indeed, the magnitude of these problems threatens the feasibility of the large-scale operational system model.

In a reasonably long time frame, these problems can be dealt with effectively only through the establishment of a formal data base system. One shot or infrequent periodic updating of the data base will severely restrict the scope and relevance of the high level analysis and result in rapid obsolescence of the operational system model. Furthermore, the high degree of interdependence among various data files and related measurement processes requires a systems framework to provide the necessary comprehensive perspective and decision oriented structure.

This data base system requirement parallels elements of the "Information Gathering, Classifying and Storage Phase of a TYPE 3 Information System" set forth by Prince in Information Systems for Management Planning and Control[1] In fact, the TYPE 3 information system characterizes many aspects of the advanced management environment predicated as a prerequisite to the high level analysis. Where the management information system is significantly less developed than the TYPE 3 system, cost-benefit relationships would not support the high level analysis and limited systems resources could be applied more effectively to other purposes.

In the advanced management environment, a large proportion of all information flows are processed or stored in computer based systems. In this context, the marginal cost of capturing or resorting an incremental data specification is extremely low. If a particular data requirement can be captured while it is online in an existing computer based processing system, the incremental cost may be negligible.

In order to facilitate this online data capture, the existing computer based system must be sufficiently flexible and sophisticated to permit online access to information flows and incorporation of special purpose data base routines where required. The existence of a well developed "Systems Processing Phase" (Prince, p. 269) would provide this capability. Again, the relevant advanced management environment would include some functional equivalent to this capability.

This kind of online data capturing flexibility is particularly important as the system model is heuristically modified and expanded over time. New or refined data requirements must be accommodated on a timely, continuing basis to support the high level analysis as new systems alternatives and information requirements are explored.

In the context of the field study introduced above, a hybrid data acquisition system including both manual and computer based operations was employed. While extensive online data acquisition opportunities were identified and evaluated, resource and time constraints together with the experimental nature of the project restricted the development of a full scale data base system. Nevertheless, this hybrid system provided an opportunity to explore significant dimensions of the data acquisition and analysis process.

Among the unique data files required for the field study system model were those relating to order submission distributions for each sales branch and computer based and manual credit review experience with incoming orders. These files represent interesting examples of data requirements which lie outside the conventional financial accounting system. To illustrate the scope and magnitude of even these limited, preliminary data requirements, the file descriptions for the order entry sample and the credit review sample are presented in Exhibits 6.1 and 6.2 respectively. These files alone required almost 19,000 computer punch cards containing nearly 200,000 data fields. These data were accumulated manually over an 18-month period. Adequate updating and maintenance of these files clearly requires an online data base system.

DATA PROCESSING AND ANALYSIS

Data processing and analysis requirements like data definition must be developed in a heuristic, iterative manner paralleling the evolution of the system model. This implies a continuing process of redefinition and refinement throughout the high level analysis process.

The initial systems model, directed at broad systems relationships, can be adequately supported by rather coarse data analysis and estimates. In the process of establishing an operational base for investigating broad relationships, highly precise or refined data analysis may prove to be undesirable. There may be a tendency to overwork data files which are readily available, producing spurious accuracy and detail relating to specific subsystems. This result may erroneously emphasize the significance of these subsystems in the total systems model and obscure other significant relationships which were not initially perceived. Furthermore, this imbalance in the systems model may influence the process of heuristic analysis, generally in such a way as to reinforce initial perceptions or

EXHIBIT 6.1

ORDER ENTRY SAMPLE FILE DESCRIPTION

Number of Records: 15,700

Record Design: Format (I2, I3, 5I2, I1)

FIELD	CHARACTER	DESCRIPTION
Fiscal Week	1-2	
Branch #	3-5	
Month	6-7	1 to 12
Day	8-9	1 to 31
Hour	10-11	1 to 24
Minute	12-13	1 to 60
Total Orders	14-15	
Type	16	1 = Parent/Teacher 2 = On Approval 3 = School/Library

EXHIBIT 6.2

CREDIT REVIEW SAMPLE FILE DESCRIPTION

Number of Records: 3,125

Record Design: Format (I6, I1, I3, I4, I3, I4, 17I3)

FIELD	CHARACTER	DESCRIPTION
Order Identification		
Date	1-6	68 MM DD
Payday	7	Codes 1 to 5
Branch #	8-10	
Total Orders	11-14	
Received for Credit		
Total	15-17	
Percent	18-21	Percent Times 1000
S.F.	22-24	
S.S.	25-27	
Br. Request	28-20	
Accepted		
Regular	31-33	
Throwbacks	34-36	
Total	37-39	
Rejected		
S.F. #	40-42	
S.F. %	43-45	Percent Times 1000
S.F. Max %	46-48	Percent Times 1000
S.S. #	49-51	
S.S. %	52-54	Percent Times 1000
C.R. #	55-57	
C.R. %	58-60	Percent Times 1000
Total Rejections		
R	61-63	
K	64-66	
Total	67-69	
%	70-72	Percent Times 1000

conclusions.

As the system model is developed and explored over time, iterative sensitivity testing may reveal the need for more complete or more precise data analysis in specific areas. Accordingly, the data analysis process must continue to respond to the requirements of the evolving systems model. Here again, the importance of an effective data base system must be stressed. Changing data and analysis requirements must be accommodated on a timely basis to support the high level analysis process and continuing heuristic analysis implies continuing changes in data requirements.

An important aspect of the initial modeling and data analysis is the potential for realizing significant immediate benefits from spinoff systems projects. The availability of new data in the context of a comprehensive system model may suggest numerous possibilities for operations research studies. Furthermore, the explicit modeling of systems relationships may reveal straightforward, but previously unrecognized opportunities to improve systems performance. Recognition of these opportunities may result as much from management participation in the preliminary modeling effort as from any specific data analysis activities.

In the context of the field study, preliminary data analysis activities were pursued both manually and by means of numerous computer based studies. A number of perceived relationships and hypotheses were tested and refined through these analyses. A sampling of the computer based studies pertaining to the order entry and credit review data introduced above are listed in Exhibit 6.3, which is an extract from the table of contents of the compiled studies.

As an example of newly perceived relationships derived from this preliminary data analysis, part of an output from the third computer based study referred to above is presented in Exhibit 6.4. This frequency distribution of numbers and percent of orders received each half hour of the day is based on a sample of nearly 126,000 time stamped orders over approximately three months. This data sort clearly indicates a clustering of order arrivals in the morning shortly after the cashiering department begins operation. This morning clustering is particularly apparent (from another sort) on Mondays.

The evident cause of this clustering is that mail arrivals accumulate at the post office overnight (and particularly over a weekend) resulting in heavy early morning mail pickups. This bunching of orders causes a wave of heavy volume through the sequential processing operations across the day while there may be idle time in the system early in the morning before the orders clear cashiering and later on in the day when the wave has passed. Due to the sequential structure of the order processing system, this pattern of volume cannot be handled efficiently.

Of course, a simple solution to this problem is the establishment

EXHIBIT 6.3

COMPUTER-BASED DATA ANALYSIS STUDIES

1. Order Entry Sample Sort by:
    - Fiscal Week
    - Type of Order

2. Order Entry Sample Sort by:
    - Fiscal Week
    - Branch

3. Order Entry Sample Sort by:
    - Half Hour of Day

4. Order Entry Sample Sort by:
    - Branch
    - Half Hour of Day

5. Order Entry Sample Sort by:
    - Payday
    - Day of Week
    - Half Hour of Day

6. Order Entry Sample (all orders) Sort by:
    - Branch
    - Day of Week
    - Half Hour of Day

7. Order Entry Sample (parent-teacher orders only) Sort by;
    - Branch
    - Day of Week
    - Half Hour of Day

8. Order Entry Sample Sort by:
    - Fiscal Week
    - Payday
    - Day of Week
    - Half Hour of Day

9. Analysis of Order Editing Data

10. Analysis of Credit Review Data (all branches together)

11. Analysis of Credit Review Data (for each branch)

EXHIBIT 6.4

ANALYSIS OF ORDER ENTRY DATA BY TIME RECEIVED

TIME PERIOD	ORDERS	PERCENT
0.00- .30	0	0.00
.30- 1.00	0	0.00
1.00- 1.30	0	0.00
1.30- 2.00	0	0.00
2.00- 2.30	0	0.00
2.30- 3.00	0	0.00
3.00- 3.30	0	0.00
3.30- 4.00	0	0.00
4.00- 4.30	0	0.00
4.30- 5.00	0	0.00
5.00- 5.30	0	0.00
5.30- 6.00	0	0.00
6.00- 6.30	0	0.00
6.30- 7.00	0	0.00
7.00- 7.30	1192	.95
7.30- 8.00	7122	5.66
8.00- 8.30	15246	12.12
8.30- 9.00	13225	10.51
9.00- 9.30	11160	8.87
9.30-10.00	8179	6.50
10.00-10.30	5317	4.23
10.30-11.00	9399	7.47
11.00-11.30	7047	5.60
11.30-12.00	3503	2.78
12.00-12.30	4194	3.33
12.30-13.00	4127	3.28
13.00-13.30	5696	4.53
13.30-14.00	6942	5.52
14.00-14.30	4630	3.68
14.30-15.00	6889	5.48
15.00-15.30	5445	4.33
15.30-16.00	3211	2.55
16.00-16.30	1953	1.55
16.30-17.00	788	.63
17.00-17.30	225	.18
17.30-18.00	298	.24
18.00-18.30	8	.01
18.30-19.00	15	.01
19.00-19.30	0	0.00
19.30-20.00	0	0.00
20.00-20.30	0	0.00
20.30-21.00	0	0.00
21.00-21.30	0	0.00
21.30-22.00	0	0.00
22.00-22.30	0	0.00
22.30-23.00	0	0.00
23.00-23.30	0	0.00
23.30-24.00	0	0.00

of an early morning swing shift in cashiering which can begin processing orders and accumulate an output queue before the other processing departments begin operation. It was confirmed that the post office could cooperate with a late night mail delivery to accommodate this swing shift.

While this obvious system modification is extremely straightforward, it was not perceived until the rudimentary order entry data were examined in a total system context. Even this minor system modification provided worthwhile potential benefits which were immediately realizable.

Continuing with the analysis of order entry data, a somewhat more elaborate breakdown of order submission relationships is presented in Exhibit 6.5. This classification of order receipts by pay cycle, day of week and half hour of day was produced by the fifth computer based study referred to above.

This sorting of order entry data reveals a number of potentially significant patterns in new order volume across the week and among pay cycles. The peaking of order receipts at the cutoff for each pay cycle is clearly evident. Furthermore, it can be seen that certain pay cycles behave better than others with regard to the evenness of order entry distributions and total volume is not equally distributed among pay cycles.

These patterns of order receipts contribute to the problems of coordinating sequential processing activities and resource budgeting

EXHIBIT 6.5

EXTENDED ANALYSIS OF ORDER ENTRY DATA

PAYDAY 1 (13.91 PERCENT)

HALF HOUR/DAY

DAY	07.0 07.5	07.5 08.0	08.0 08.5	08.5 09.0	09.0 09.5	09.5 10.0	10.0 10.5	10.5 11.0	11.0 11.5	11.5 12.0	12.0 12.5	12.5 13.0	13.0 13.5	13.5 14.0	14.0 14.5	14.5 15.0	15.0 15.5	15.5 16.0	16.0 16.5	16.5 17.0	17.0 17.5	17.5 18.0	18.0 18.5	18.5 19.0	DAY/WEEK
1	.3	3.3	7.6	24.1	18.2	11.8	3.8	1.7	1.2	.2	1.1	1.0	17.7	2.2	4.6	.3	.4	.2	.2	0.0	0.0	0.0	0.0	0.0	10.28
2	0.0	4.4	17.6	6.5	9.5	2.3	3.0	3.0	18.9	2.3	.8	1.1	.4	3.0	6.6	5.0	9.0	2.0	3.9	.4	.2	0.0	0.0	0.0	19.10
3	.9	3.3	10.6	5.2	12.6	7.5	8.1	5.8	2.2	5.5	2.5	.2	9.3	9.9	5.3	4.3	3.3	2.4	.1	0.0	.8	0.0	0.0	0.0	21.97
4	1.7	10.4	13.2	4.5	5.8	3.1	3.7	12.9	11.7	3.6	2.2	2.0	6.5	3.4	.7	5.8	4.2	1.7	1.3	.9	.6	.2	0.0	0.0	34.35
5	5.5	7.0	21.7	2.9	7.1	8.0	9.0	4.2	2.3	1.3	2.7	1.0	8.1	4.2	4.2	3.3	2.8	5.1	.3	.1	0.0	0.0	.1	0.0	10.49
6	0.0	0.0	0.0	35.9	56.5	0.0	2.0	0.0	0.0	0.0	.3	0.0	5.1	0.0	.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.70
7	0.0	0.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.11
	1.4	6.2	13.3	8.0	11.3	5.2	4.9	6.9	8.5	3.0	1.9	1.1	7.2	4.6	3.6	4.2	4.2	2.0	1.3	.4	.4	.1	.0	0.0	

PAYDAY 2 (22.13 PERCENT)

HALF HOUR/DAY

DAY	07.0 07.5	07.5 08.0	08.0 08.5	08.5 09.0	09.0 09.5	09.5 10.0	10.0 10.5	10.5 11.0	11.0 11.5	11.5 12.0	12.0 12.5	12.5 13.0	13.0 13.5	13.5 14.0	14.0 14.5	14.5 15.0	15.0 15.5	15.5 16.0	16.0 16.5	16.5 17.0	17.0 17.5	17.5 18.0	18.0 18.5	18.5 19.0	DAY/WEEK
1	4.4	3.8	22.9	26.5	12.6	7.1	2.1	.7	.1	1.2	0.0	0.0	4.3	1.7	10.4	.2	1.4	.1	.4	0.0	0.0	0.0	0.0	0.0	8.72
2	0.0	2.7	10.3	6.9	7.5	12.1	1.2	7.2	7.0	7.8	5.8	4.0	5.0	3.2	.9	7.4	4.3	2.9	.8	2.6	.5	0.0	0.0	0.0	14.71
3	0.0	2.0	5.3	10.0	3.0	4.9	1.1	6.4	3.4	4.3	2.5	2.7	3.1	17.0	13.3	14.7	4.3	2.0	.0	0.0	0.0	0.0	0.0	0.0	18.75
4	.3	8.3	12.1	7.3	4.4	2.9	11.9	12.5	11.5	4.3	.2	1.8	6.8	.1	2.9	3.6	5.2	1.0	2.8	0.0	0.0	0.0	0.0	0.0	15.24
5	.6	4.5	9.5	17.2	7.5	6.1	3.3	7.7	9.2	3.1	1.7	.4	6.1	9.5	3.3	3.3	4.8	1.5	.3	.1	0.0	.1	0.0	.1	37.14
6	10.9	0.0	46.7	0.0	35.5	0.0	0.0	0.0	.3	1.8	0.0	3.7	0.0	1.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.30
7	0.0	0.0	0.0	0.0	0.0	0.0	63.2	0.0	0.0	0.0	34.2	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.14
	1.2	4.0	12.4	12.7	8.1	6.0	3.7	7.1	6.9	4.0	2.0	1.7	5.0	7.4	5.2	5.7	4.1	1.5	.7	.4	.1	.0	0.0	.0	

PAYDAY 3 (18.58 PERCENT)

HALF HOUR/DAY

DAY	07.0 07.5	07.5 08.0	08.0 08.5	08.5 09.0	09.0 09.5	09.5 10.0	10.0 10.5	10.5 11.0	11.0 11.5	11.5 12.0	12.0 12.5	12.5 13.0	13.0 13.5	13.5 14.0	14.0 14.5	14.5 15.0	15.0 15.5	15.5 16.0	16.0 16.5	16.5 17.0	17.0 17.5	17.5 18.0	18.0 18.5	18.5 19.0	DAY/WEEK
1	1.5	7.8	20.7	16.0	19.2	12.6	4.5	4.6	1.7	.5	3.0	1.1	2.2	1.1	.5	1.8	.4	.3	.0	.5	0.0	.1	.0	0.0	41.49
2	3.1	.3	1.7	12.5	6.6	1.6	1.8	4.1	3.2	1.1	3.6	1.2	1.3	5.0	13.5	15.7	11.3	1.3	9.8	1.2	0.0	0.0	0.0	0.0	9.27
3	1.4	2.9	12.9	6.1	4.2	1.9	2.1	3.0	2.1	.3	4.1	1.1	4.9	8.1	6.6	16.9	8.0	11.2	2.3	0.0	0.0	0.0	0.0	0.0	12.93
4	.4	10.5	14.7	5.7	6.4	7.3	4.3	8.1	6.9	2.9	3.0	3.4	4.8	.7	.2	6.2	5.6	8.6	.1	0.0	0.0	0.0	0.0	0.0	13.98
5	1.0	6.7	14.3	5.5	6.9	6.3	3.2	7.8	4.8	1.6	4.2	3.8	6.9	1.9	.4	9.4	12.7	1.9	.3	.4	0.0	0.0	0.0	0.0	16.80
6	0.0	6.5	17.4	13.9	19.5	.4	14.6	8.2	4.7	0.0	2.1	7.6	2.1	0.0	0.0	0.0	2.8	.1	0.0	0.0	0.0	0.0	0.0	0.0	3.83
7	24.2	8.3	13.2	8.5	10.0	1.5	4.3	0.0	6.5	0.0	14.2	0.0	1.0	0.0	0.0	4.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.72
	1.7	6.6	15.8	11.0	12.1	7.7	4.1	5.4	3.3	1.0	3.5	2.1	3.6	2.4	2.4	6.9	5.4	3.2	1.3	.4	0.0	.0	.0	0.0	

EXHIBIT 6.5

(Continued)

PAYDAY 4 (22.00 PERCENT)

DAY	07.0–07.5	07.5–08.0	08.0–08.5	08.5–09.0	09.0–09.5	09.5–10.0	10.0–10.5	10.5–11.0	11.0–11.5	11.5–12.0	12.0–12.5	12.5–13.0	13.0–13.5	13.5–14.0	14.0–14.5	14.5–15.0	15.0–15.5	15.5–16.0	16.0–16.5	16.5–17.0	17.0–17.5	17.5–18.0	18.0–18.5	18.5–19.0	DAY/WEEK
	HALF HOUR/DAY																								
1	.3	4.9	25.9	18.7	10.6	15.8	4.7	3.4	2.0	8.0	1.6	.1	.6	.9	1.7	.0	.5	.4	0.0	.0	0.0	0.0	0.0	.1	14.95
2	.3	7.5	7.5	5.5	3.4	6.0	4.6	7.0	5.2	1.7	2.3	10.4	7.4	8.9	4.9	3.4	4.3	2.7	2.4	1.9	.9	1.4	.0	0.0	45.51
3	2.9	16.5	14.1	4.2	10.1	.5	4.2	1.4	5.2	.4	12.5	1.4	4.0	8.2	.9	4.7	1.4	2.6	3.7	1.2	0.0	0.0	0.0	0.0	13.79
4	.1	.7	8.6	3.6	5.3	0.0	10.9	11.9	2.8	7.2	.9	4.6	8.7	5.5	.6	3.9	6.2	6.4	12.2	.0	0.0	0.0	0.0	0.0	10.07
5	0.0	1.3	10.8	9.3	4.2	0.0	2.9	5.7	3.5	1.1	14.4	5.0	3.5	3.8	2.8	8.5	14.2	6.5	.2	2.3	0.0	0.0	0.0	0.0	11.55
6	0.0	0.0	13.1	71.3	0.0	1.2	13.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.68
7	0.0	0.0	2.4	0.0	22.4	0.0	0.0	0.0	0.0	0.0	48.8	0.0	0.0	11.2	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.45
	.6	6.6	11.8	9.9	5.6	5.2	5.3	5.8	4.1	2.9	5.0	6.0	5.3	6.4	3.1	3.6	4.5	3.0	2.9	1.3	.4	.6	.0	.0	

PAYDAY 5 (23.38 PERCENT)

DAY	07.0–07.5	07.5–08.0	08.0–08.5	08.5–09.0	09.0–09.5	09.5–10.0	10.0–10.5	10.5–11.0	11.0–11.5	11.5–12.0	12.0–12.5	12.5–13.0	13.0–13.5	13.5–14.0	14.0–14.5	14.5–15.0	15.0–15.5	15.5–16.0	16.0–16.5	16.5–17.0	17.0–17.5	17.5–18.0	18.0–18.5	18.5–19.0	DAY/WEEK
	HALF HOUR/DAY																								
1	.1	5.2	16.7	17.3	14.5	5.7	9.5	5.7	10.0	4.3	1.7	4.7	2.6	.4	.2	.9	.2	.4	0.0	0.0	0.0	0.0	0.0	0.0	13.92
2	0.0	2.3	3.8	1.3	4.3	6.3	4.5	13.3	7.7	2.9	2.8	5.3	3.7	5.8	6.2	8.8	8.9	3.3	6.8	2.0	0.0	0.0	0.0	0.0	21.28
3	.6	6.8	13.4	11.2	8.1	5.2	5.2	8.8	4.8	1.3	3.3	2.7	3.3	5.2	5.8	8.2	3.6	1.4	.1	.0	.5	.5	0.0	0.0	40.84
4	0.0	4.5	8.0	1.4	21.0	3.6	4.2	11.7	10.5	2.7	9.7	1.0	7.9	6.0	2.5	3.1	.7	1.5	.0	0.0	0.0	0.0	0.0	.1	10.93
5	.1	5.3	8.5	4.9	14.6	5.1	3.9	7.7	2.3	.4	1.4	12.7	3.4	4.3	.0	9.9	8.7	5.6	1.0	.0	0.0	0.0	0.0	.1	9.97
6	0.0	0.0	1.9	15.4	19.1	48.1	3.6	0.0	0.0	0.0	.6	6.6	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.39
7	2.0	5.1	23.0	0.0	0.0	.5	16.8	.5	9.7	0.0	16.3	0.0	0.0	0.0	9.2	0.0	16.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.67
	.3	5.1	10.5	8.3	10.5	6.3	5.4	9.3	6.4	2.1	3.5	4.4	3.8	4.5	4.1	6.7	4.4	2.0	1.6	.4	.2	.2	0.0	.0	

TOTAL ORDERS = 125452.00

discussed above. While the direct modification of specific sales branch behavior may involve difficult political problems, aggregate volume patterns can be adjusted at a first approximation level by reassigning sales branches among pay cycles. Substantial benefits could be realized from this straightforward adjustment while more complex policy and systems alternatives are being evaluated.

More disaggregated sorts similar in format to Exhibit 6.5 for each sales branch revealed a rather broad range of order submission behavior among branches. By selecting an appropriate mix of sales branches for each pay cycle, smoother, more uniform aggregate volume distributions could be achieved. Using the disaggregated order entry files as a data base and the aggregate order entry sort as a simulator, the assignment of sales branches can be explored heuristically and specific assignment configurations can be evaluated empirically using historical relationships. Again, this immediate approach to a significant problem area is a direct spinoff from the data acquisition and analysis activities required for the high level analysis and involves very little incremental cost or special resources.

A final example of systems projects initiated through the data acquisition and analysis process involves a resource allocation model in the telephone communications area. A more complete description of this project and related implications is contained in "Computer Modeling and Simulation: A Management Tool for Systems Definition and Analysis," (Financial Executive, September 1970, pp. 20-27) by

James B. Thies.

In this spinoff study, the heavy and highly variable use of long distance telephone communications in the credit review, collections and sales management areas was analyzed in relation to alternative wide area transmission services available as well as alternative operating policies in the relevant processing departments. A computer-based simulation model encompassing this multi departmental telephone usage system was developed in FORTRAN and used to evaluate alternative system configurations. Based primarily on data files developed in the course of the high level analysis, this model revealed substantial potential cost savings while requiring very little incremental analysis.

Moreover, this modest project proved to be a valuable vehicle for introducing management to the methodology and potential of computer-based modeling and simulation. The limited scope of the project together with the highly visible and easily understood structure of the system provided a useful context for reviewing the entire analysis, modeling and simulation process free from burdensome complexity. As a result, the most significant payoffs realized from the project may have been in the area of management education and involvement quite apart from the specific recommendations regarding resource allocation.

In summary, the data acquisition and analysis process involves more than the development of a data base for the system modeling effort. The data analysis process is a direct as well as an instrumental aspect of the high level analysis. The direct aspect of data analysis activities is significant not only in the identification and structuring of subsidiary systems projects but also in the continuing process of redefining and refining system relationships in support of heuristic modeling and evaluation of system alternatives.

COMPUTER-BASED MODELING

Computer-based modeling constitutes the process of translating the systems structure and relationships defined through the systems analysis into formal computer programs incorporating the quantitative relationships determined through empirical data analysis. The formal computer-based modeling effort is highly interdependent with other aspects of the high level analysis. Elements of formal modeling must be considered and reconsidered throughout the organization review, systems analysis and data acquisition and analysis phases. The total analysis process is necessarily iterative. Data definition will depend in part upon characteristics of the computer-based model which are based upon systems relationships in turn perceived through data analysis. Accordingly, the organization of the following discussion should not be construed to suggest that specific activities are independent or can be executed fully in sequential order.

The computer-based modeling process involves a number of technical areas worthy of consideration. Selected aspects of the modeling process are discussed in three sections below: (1) Hardware and Software Requirements, (2) Developing the Simulator, and (3) Model Integration and Implementation. A technical appendix to Chapter VI is included to provide summary program documentation pertaining to the computer-based model developed in the field study.

1. Hardware and Software Requirements

Throughout the preceding discussion it has been repeatedly stressed that the formal model building process must minimize preconceptions and rigid analytic viewpoints, must constitute a viable vehicle for continuing management involvement, and must provide sufficient flexibility and adaptability to support heuristic analysis over a broad range of possible inquiries. While these objectives are essential to the high level analysis, they can be easily lost or obscured in the computer-based modeling process. Indeed, many simulation based studies have undoubtedly failed to produce desired or expected benefits due to the constraints and unique requirements encountered in computer-based modeling. However, many of these problems can be overcome through the selection of an appropriate computer hardware and software configuration.

A number of relevant criteria can be identified to define the characteristics of such an appropriate configuration. The programming language must be well established with sufficient documentation and continuing support to assure the availability of technical assistance and required operating systems and personnel. The language must be operational on a broad variety of general purpose digital computers to avoid overt obsolescence and undue constraints in hardware availability. The structure of the language must facilitate simulation oriented modeling with a minimum of programming and debugging difficulties. Furthermore, the ultimate computer code generated must be reasonably efficient with regard to computer storage requirements and program execution speed.

Beyond these technical requirements, the programming language must support the broad objectives of the high level analysis. The structure and logic of the programming language must be explicit and easily understood to facilitate active participation in the modeling process by management personnel who do not have a technical background in computer programming. A language built around English oriented syntax and common mathematical notation may be demanded as a minimum requirement in this context. While it is not suggested that upper management personnel need to be involved in detailed programming activities, they must be capable of comprehending the structure and operation of the formal model and conceptualizing relevant changes and modifications. These requirements cannot be lodged exclusively with technical support staff without significantly compromising the objectives and potential of the high level analysis.

A somewhat related user oriented software requirement is the ability to integrate program, parameter, and variable changes in the model on a timely, orderly basis. Effective heuristic analysis must be supported by prompt response to evolving inquiries, perceptions and conclusions. Accordingly, the programming environment must be highly flexible and adaptive over a broad range of possible demands. If program modifications consistently require extensive analysis, patching of existing code and reintegration and debugging of program logic, the potential contribution of the computer-based analysis will be significantly restricted. Effective use of modular programming and reliance on computer generated machine code may be particularly important in this regard.

Finally, the modeling process constitutes a dynamic representation of evolving perceptions and inquiries. The structure and logic of the modeling medium is as much a part of this representation as the real system under examination. In fact, characteristics of the programming environment may significantly influence or constrain the translation of system relationships into modeled representations. For example, a programming language which is specifically designed to facilitate modeling of queueing systems may result in an inappropriate emphasis on queueing relationships or a language which requires extraordinary adaptation to incorporate stochastic processes may inappropriately encourage the perception of deterministic relationships. In summary, the world view or systems perspective explicitly or subtly incorporated in a specific modeling environment, may significantly influence the formal modeling process. In the long run, these factors may have a more important impact on the total analysis than will the mechanical aspects of a particular hardware and software configuration.

Of the several dozen programming languages commonly available, at least 40 are represented to be specifically designed to facilitate computer modeling and simulation. Beyond these, practically any of the "non-simulation" languages can be used, with varying degrees of difficulty, in a modeling and simulation context. While even a semi-exhaustive evaluation of these many languages is beyond the scope of this discussion, an abbreviated review of the major alternatives available in terms of the objectives and requirements outlined above may be useful.

Many organizations rely almost entirely on machine code or assembly level programming for general data processing requirements. This hardware oriented programming often results in material advantages with regard to hardware utilization and operating efficiency and may facilitate training of programming staff who do not have a broad background in computer technology. These factors may be particularly significant in a data processing environment where relatively simple programs are used repeatedly over a long period of time.

In the context of the high level analysis, it can be immediately observed that machine language programming is generally highly hardware dependent, requires very detailed disaggregated logic and instructions and accordingly involves more extended programming and debugging efforts. As a result it is difficult to conceptualize broad systems relationships in terms of program logic and heuristic program modifications are more difficult to specify and implement. These shortcomings generally dominate related technical efficiencies to such an extent that machine language programming is almost uniformly inappropriate for large scale modeling and simulation efforts.

Exceptions may arise when (1) excess programming resources are available with a low marginal cost, (2) the simulator is conceptualized with modest scope and complexity and (3) severe hardware constraints compel the use of highly technically efficient code. These conditions would be particularly applicable to a relatively independent utility function supporting the main simulator which must be utilized frequently and has little direct interaction with the model structure or logic. As long as these utility functions can be maintained as independent modules requiring little modification as the main simulator evolves over time, important technical efficiencies may be realized without compromising the objectives of the high level analysis.

Moving beyond assembly level languages, a number of general purpose compiler languages such as FORTRAN, ALGOL and PL/I have been used effectively in computer modeling and simulation. These languages are much less hardware dependent, can be dealt with through standard mathematical notation, provide a higher level or more aggregate programming orientation and generate acceptably efficient or optimized machine code. Probably due to the wide availability of programming resources and documentation at this level, most existing simulation efforts have been executed in one or more of these compiler languages.

While general purpose compilers may satisfy most of the programming criteria outlined above, a number of important limitations and corresponding potential extensions remain. Large scale computer-based modeling and simulation commonly requires several special purpose capabilities such as list processing functions, dynamic storage allocation and memory word packing which are difficult or at least awkward to provide through general purpose packages. As a result, the required program logic becomes so complex and involved that the formal modeling process fails to provide a viable basis for systems conceptualization and an explicit vehicle for structuring management experience and perceptions at an acceptably nontechnical level. Furthermore, simulation based analysis involves a number of computational processes and standard utility routines which are often used repeatedly across a broad range of applications. The use of software packages designed to provide these functions rather than attempting to develop each capability from a general purpose language as required may result in significant resource economies both in program development and evolution over time.

In response to these requirements, a number of software packages designed to be compatible with established general purpose compilers have been developed. Many of these packages are addressed to the specific characteristics of modelled systems. Accordingly, sets of routines have been developed specifically to facilitate simulation based analysis of job shop scheduling, sequential queueing, inventory control and several transportation problems. While these packages have contributed significantly in their respective application areas, in general they are too narrow in conception and implementation to effectively support the high level analysis process.

Several sets of software packages became so well developed over time, that it was possible to integrate their various special purpose functions and add a limited number of more general purpose capabilities to produce entire stand-alone compiler languages specifically addressed to simulation applications. While most of the approximately 10 such languages currently available retain the specific application orientation of their antecedents, a small number are represented to be truly general purpose simulation languages. This general purpose orientation is important in the context of the high level analysis where a major objective is to heuristically model perceived systems relationships rather than mold or transform these relationships to fit a preconceived world view or analytic structure.

Among the several general purpose simulation languages currently available (1) CORC[2], (2) CSL[3], (3) GASP[4], (4) GPSS[5], (5) SIMSCRIPT[6], and (6) SOL[7], are perhaps the best established and have received particular attention in the literature.[8] Within this set, GPSS and SIMSCRIPT are by far the most developed, thoroughly documented and widely implemented. Due primarily to heavy and continuing support by IBM, GPSS is undoubtedly the most widely used simulation compiler across a variety of application areas, while SIMSCRIPT occupies a rather distant but growing second place position.

As between GPSS and SIMSCRIPT, it is commonly observed that GPSS is less difficult and faster to implement as a coarse representation of systems relationships due to its underlying structure of packaged, macro processing functions, effective debugging diagnostics and widely available documentation and systems support. These advantages are realized at the expense of large scale hardware requirements, long processing times and generally limited flexibility beyond the specified set of macro processing capabilities. This limited flexibility strongly encourages, if not compels, formal modeling of system interactions in terms of the queueing relationships upon which the structure of the language is based.

SIMSCRIPT is a more generally conceived language with greater flexibility and unstructured computational power. Because it relies less heavily on predefined macro processing functions (which may not be relevant to a specific application), SIMSCRIPT generally results in more efficient hardware utilization and requires less processing time. At the same time, however, this level of flexibility and generality requires detailed specification of systems relationships in explicit program logic and may necessitate more sophisticated programming and implementation support. Given this support, the logical structure and generality of the language facilitate adaptive, heuristic redefinition of the formal model with a minimum of software and hardware based constraints.

In summary, if the conceptual constraints embodied in GPSS are not significant in relation to the system under study and if programming and systems support resources are highly constrained while adequate hardware power and processing time are available, GPSS may represent the most satisfactory alternative as a formal modeling and simulation language. However, in the context of an advanced management environment where highly diverse and complex systems relationships are being examined, where sophisticated systems support resources are available and where continuing heuristic evolution of the computer-based model is an important aspect of the analysis process, SIMSCRIPT appears to constitute a more effective formal modeling medium. For these reasons, SIMSCRIPT was chosen as the software system for computer-based modeling and simulation in the context of the field study undertaken for this project.

2. Developing the Simulator

Translation of the conceptual systems model developed in Chapter V above into an operational computer-based model constitutes an iterative, heuristic process in several dimensions. The initial computer-based systems model can be utilized as a simulator to test the sensitivity of formally modeled relationships, parameter estimates and data inputs as well as to suggest extended analytic requirements thereby guiding the evolution and refinement of the model through time. Indeed, an essential aspect of the computer-based modeling and simulation process is this capability to use continuing experience with operationally modeled systems relationships to evaluate, refine and update the specification of these relationships. In a sense this relation parallels the process of operational definition and measurement where the object or properties to be measured must first be defined, but measurements on the object or properties are necessarily elements of the definition.

Because of the continuing heuristic nature of the formal modeling process, it is essential that management participation and understanding be maintained to the greatest extent possible. While technical support from the systems group must play a significant role in operationalizing the systems model, this support cannot dominate the model development process without sacrificing the objectives of the high level analysis. It has been repeatedly stressed in the foregoing discussion that development of the systems model is an instrumental or facilitating process rather than a set of procedures leading to a static, final product. The process of model development and evolution is undertaken to identify and evaluate significant questions or alternatives in a total systems context, rather than apply optimizing techniques to specific decision processes at a lower systems level. The realization of these objectives requires that high level decision makers participate in and effectively use the model development process, not simply the "final" model or some prescribed outputs from a simulation experiment.

For these reasons, the modeling environment, including software, hardware, and data analysis support is a significant aspect of the analysis process. Quite apart from technical efficiencies and resource constraints, characteristics of the modeling environment may significantly influence the degree to which management personnel can meaningfully participate in the development and evolution of the operational systems model and realize the potential contribution of the high level analysis process. Effective use of a high level, simulation oriented programming language such as SIMSCRIPT is an important element of this appropriate modeling environment.

In operationalizing the conceptual systems model, detailed program oriented flowcharts must be developed to define all systems relationships and processing functions to be incorporated in the initial computer-based model. Systems oriented programming languages such as SIMSCRIPT and GASP are built around an "event" or "activity" logical structure which can greatly facilitate this process. Program segments are defined in terms of processing functions which correspond both logically and tangibly to the activities and relationships represented in the conceptual systems model. Rather than generating program specifications which are hardware oriented and highly abstracted from managerial perceptions and experience with the real system, this process more directly translates these perceptions and experience into user oriented macro program instructions.

The result of this approach to computer-based modeling is an operational systems model which can be read and comprehended in terms of tangible systems relationships with only moderate technical background and assistance. This essential correspondence between formal program logic and observed systems relationships at an explicit level facilitates management involvement throughout the modeling process and provides a basis for meaningful management interaction with the evolving system model over time. This degree of explicit involvement with the operational model is required to support continuing heuristic modification, expansion and interrogation of the model in response to managerially perceived decision variables, policy alternatives and related information requirements.

A broad macro program flow chart of the SIMSCRIPT based model developed in the course of the field study supporting this project is presented in Exhibit 6.6. The main simulator program consists of

EXHIBIT 6.6

MACRO PROGRAM FLOW CHART OF SIMULATOR

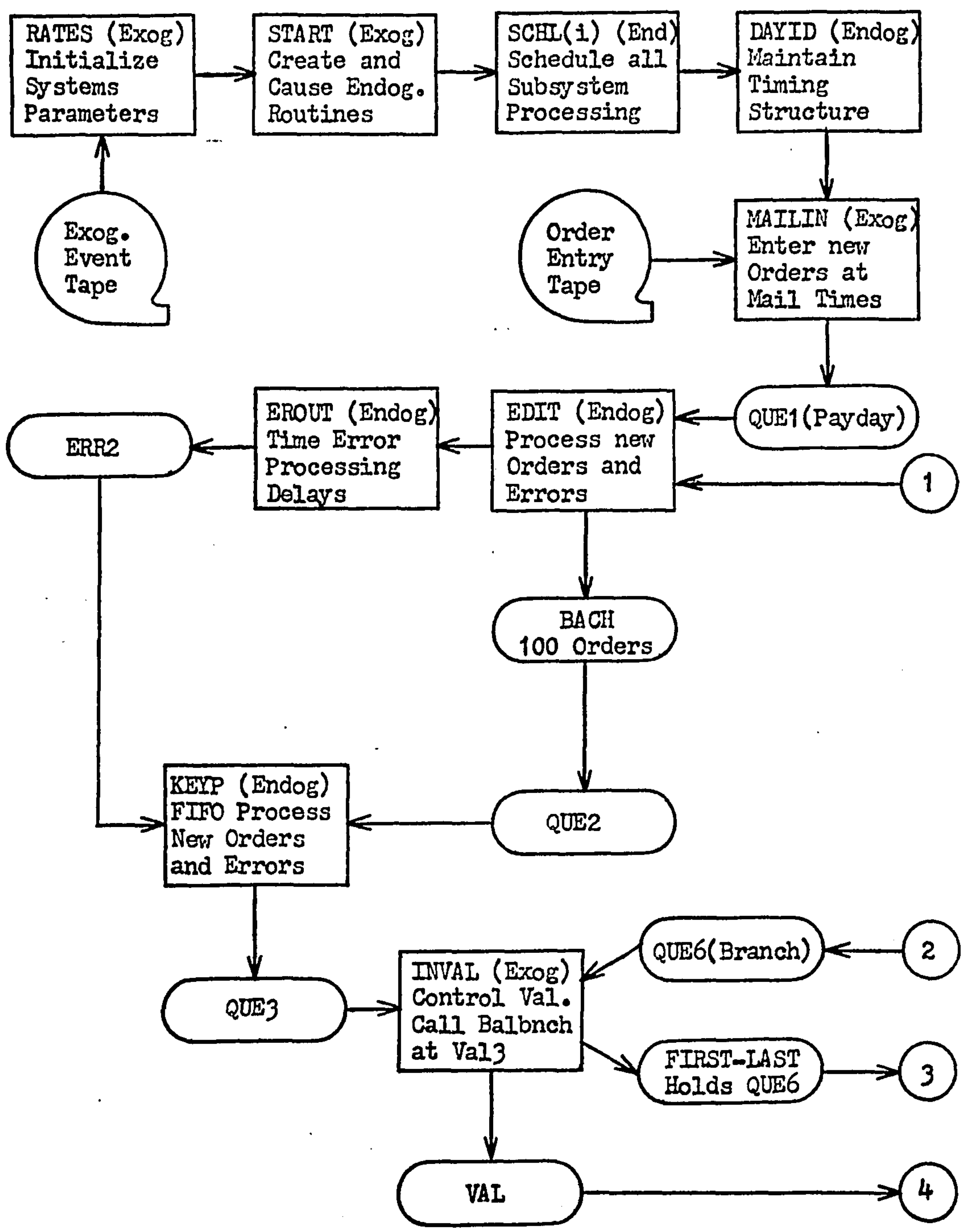
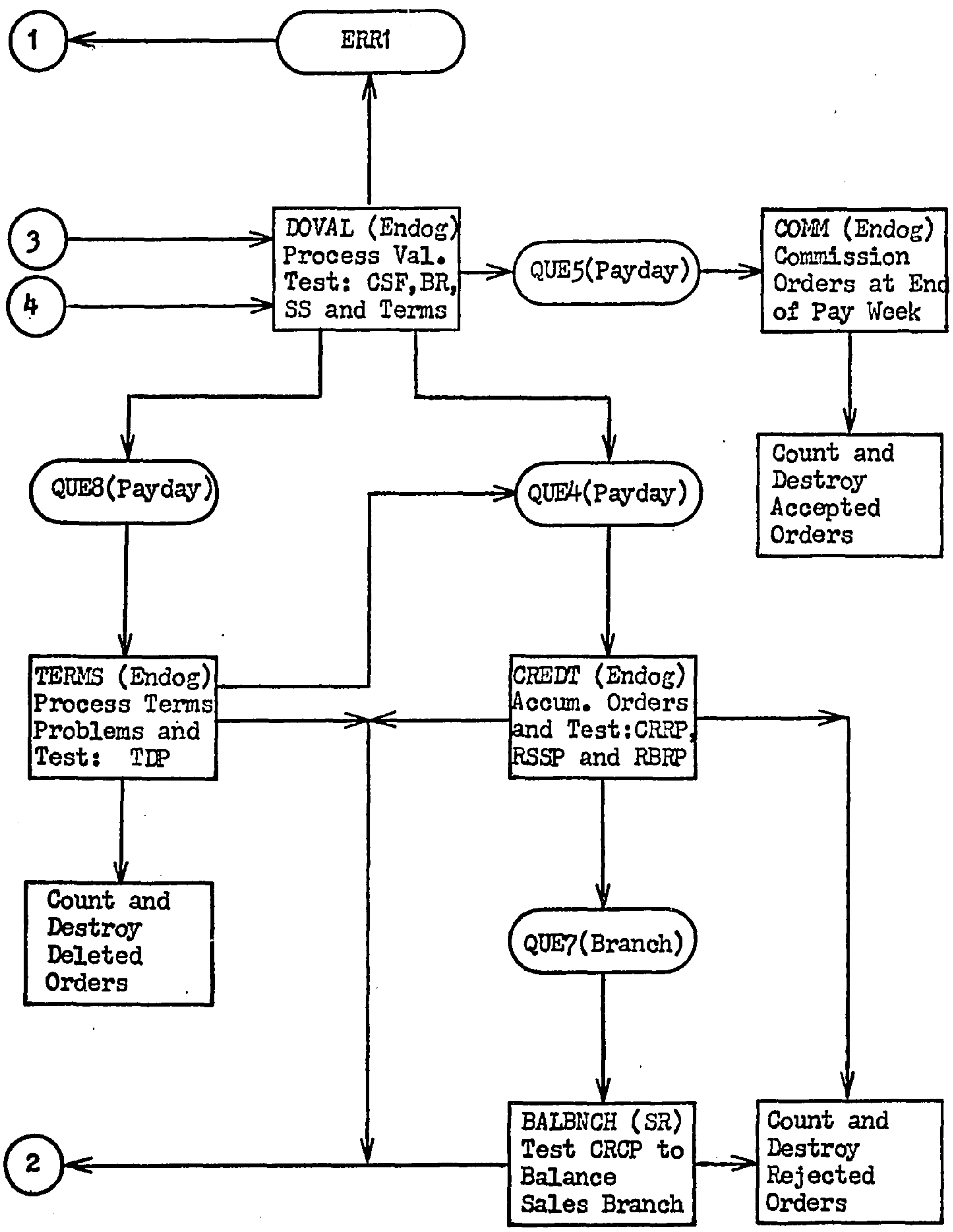


EXHIBIT 6.6

(Continued)



approximately 1,000 SIMSCRIPT statements exclusive of data and parameter files. Comparison of this program flow chart with the macro conceptual systems flow chart presented in Exhibit 5.4 above, reveals the essential logical and structural correspondence referred to above. Each functional block in the program flow chart represents a major set of systems activities, which, in this case approximately parallels the firm's departmental organization. It should be noted that this program flow chart is not complete in that a number of processing functions of a supportive character have been deleted for clarity.

While it is not within the scope or intent of this discussion to describe or generalize from the many experiences of a technical nature encountered in the development of this computer-based simulation model, a few observations and at least skeleton documentation may be appropriate. First, as Forrester and others have observed in many contexts, intuition and restricted experience are generally very poor guides for assessing the behavior of complex systems. The formal modeling experience may be expected to revise or modify management perception and understanding of systems relationships, decision processes and policy alternatives. Accordingly, it is again stressed that the modeling process is heuristic and must build upon itself iteratively over time. To this end, the programming and systems resources supporting the modeling process must be flexible and adaptable to facilitate redefinition, revision or refinement of the systems model.

Second, in a similar vein it is important not to misplace emphasis on a specific segment or aspect of the formal model because it is particularly amenable to analysis or data collection. Elaborate micro detail in specific model specifications can be fascinating and lend apparent eloquence to the formal model without contributing to the objectives of the high level analysis. In fact, the heaviness and potential awkwardness of unnecessary elaboration may impede implementation and meaningful interaction with the model and will almost certainly inhibit appropriately responsive model modifications and dynamic evolution over time. Broad ranging sensitivity analysis can be utilized effectively in evaluating the potential contribution of more precise data, more disaggregated specification of systems relationships or finer testing of decision variables. As a general principle, the simplest, most explicit representation of systems relationships which can adequately support a required line of analysis is best suited to the purpose. Refinements and more eloquent detail can be incorporated when it is demanded by more sophisticated analysis requirements.

Third, in order to facilitate continuing program modification and reimplementation over time, program logic, parameter specifications and data files should be structured in a modular fashion to the greatest extent possible. In this way, changes in specific decision rules or processing functions can be specified and operationalized without reviewing the entire program logic and necessitating scattered patches at diverse logical locations.

Similarly, sensitivity testing of parameter sets and introduction of new or revised data files can be greatly facilitated by organizing operations on these elements of the formal model in program modules which can be accessed or modified without disrupting the main simulator's logic. Several of the high level simulation compilers, including SIMSCRIPT, explicitly provide for this kind of modular program structure.

Finally, complete, accurate and reasonably uniform documentation of all aspects of the computer based model is essential to the effective use of the modeling process within the high level analysis. Indeed, the very development and understanding of this documentation is an important aspect of the analysis process serving as a formal vehicle for articulating and comprehending diverse systems relationships in a common framework. Needless to say, this documentation is also required to support continuing modification, expansion and updating of the model over time. This support is essential not only in terms of efficiently implementing proposed program changes but also to relate conceptual inquiries and information requirements to existing formal model logic.

The world view or modeling logic of the high level simulation compilers provides a useful framework for structuring program documentation. The SIMSCRIPT systems perspective is structured in terms of specifications of systems "status" and the "events" which modify this status through simulated time. Systems status is specified by "permanent entities" which constitute the formal structure of the system and "temporary entities" which constitute the throughput of the system. Entities are described in terms of their "attributes" and their membership in, or ownership of, "sets". Events are specified through subroutines which are defined as "exogenous" or "endogenous" depending upon whether the time phasing of their execution is independent of system status or a result of system status. This abstract structure of modeling logic is highly unconstrained with respect to the content or substance of the system being analyzed, yet the logical form provides a useful framework for organizing the specification of systems relationships in an orderly, explicit fashion.

While the complete documentation underlying the computer based model developed in the context of the field study extends beyond the scope of this discussion both in quantity and technical detail, a sampling of summary documentation may provide richer insight into the implications of the macro program flow chart presented in Exhibit 6.6 and the relation of the SIMSCRIPT logical structure to the modeling process. For this purpose, a summary listing and description of the permanent entities, temporary entities, attributes, sets and events which constitute the formal computer based model are presented in an appendix to this chapter. Selected program flow charts for the subroutines underlying key simulation events are also included in this appendix.

3. Model Integration and Implementation

While the activities of programming, debugging and hardware implementing the computer based model are relatively mechanical in nature, they may represent important commitments of time and resources as well as reveal more significant implications for the high level analysis. These broader implications are the primary concern in this context.

Computer-based modeling of the magnitude required to support the high level analysis process may be expected to impose significant demands on hardware resources. The field study model discussed above was implemented on a Control Data 6400 computer with 65K 60 bit words only after extensive word packing, segmentation and intensive use of dynamic storage allocation to optimize core utilization. After minor software adaptations to accommodate model dynamics more efficiently, meaningful simulation runs representing approximately six months of simulated time required over 30 minutes of dedicated central processor time exclusive of pre and post simulation data formatting and analysis runs. Undoubtedly, these requirements could be reduced somewhat with more selective specification of analysis and output functions than was incorporated in these experimental runs.

The more general observation from this perspective is that large scale computer-based modeling and simulation constitutes a rather heavy vehicle of analysis. Unless the modeling process is effectively managed in relation to the objectives of the high level analysis, the very heaviness of the methodology may obscure significant relationships making the operational model a meaningless monolith rather than an adaptive instrument of analysis. Both the structure of the analysis process and the characteristics of an advanced management environment set forth in preceding chapters were directed to overcoming or minimizing these potential limitations. The implementation process must continue to support these objectives in order to realize the potential contribution of the computer-based analysis methodology.

An important dimension of this support is the ability to segment the operational systems model in order to isolate essentially systems support functions from the logical structure of the system model. To the extent that required data acquisition, pre-analysis and input formatting as well as output formatting, post-analysis and reporting functions can be separated from the simulator *per se*, the technical mass and complexity of the system model itself can be substantially reduced. The importance of this segmentation is amplified in the context of an advanced management environment where systems support functions can be integrated with existing systems capabilities at a low marginal cost. By this means the system model itself is greatly simplified both in size and intricacy thereby facilitating management comprehension and interaction as well as heuristic model adaptation and evolution over time.

These principles were incorporated in the design and implementation of the field study model utilizing numerous multi-language programs to support the SIMSCRIPT based simulator. This approach greatly increased the flexibility of using special purpose or more technically efficient programming techniques to handle large volume, involved processing functions while maintaining the more conversational, systems analysis oriented capability of SIMSCRIPT for the actual systems modeling and simulation activities. Furthermore, by effectively reducing the size of the main simulator, core and processing time requirements for simulation runs were significantly reduced resulting in improved turn around times and more flexibility with regard to hardware requirements.

This segmented approach to model implementation also provided valuable flexibility in analyzing, evaluating and formatting simulation output reports. The SIMSCRIPT based simulator was designed to create highly disaggregated output files on tape with no preliminary analysis and minimum formatting requirements. This procedure effectively bypassed the rather inefficient and constrained report generating functions incorporated in SIMSCRIPT with substantial reductions in required core and processing time. These disaggregated output files were then analyzed through a series of FORTRAN based programs to produce meaningful output reports including CALCOMP generated graphic displays. The graphic displays were found to be particularly effective for presenting copious data in a manner which immediately highlighted significant relationships in a meaningful, explicit format.

An example of the graphic displays generated is presented in Exhibit 6.7. This pseudo three dimensional display represents a response surface in the context of a resource allocation problem involving long distance telephone communications encountered in the course of the field study. Here two primary decision variables (in the plane of the observer) are plotted against average cost per communication (vertical axis) to facilitate the search for a least cost strategy. Not only is the quasi optimum strategy effectively highlighted, but also the sensitivity of the performance measure with respect to the decision variables is clearly evident. Other plotted displays were used similarly to present simulated time series data relating to a number of systems status variables.

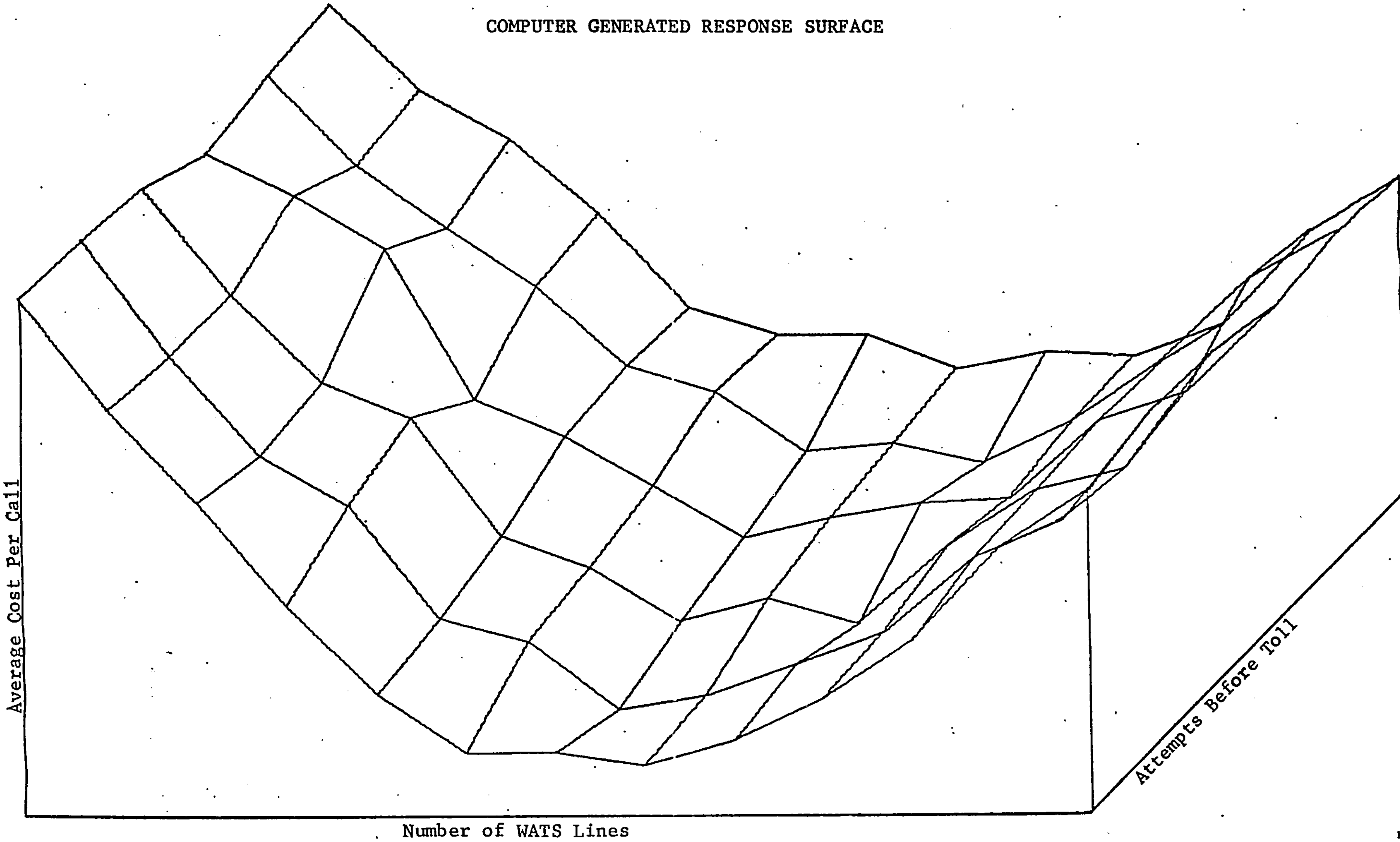
The possibility of developing a library of user oriented report generating functions capable of interrogating the disaggregated output files with a variety of analysis, report formatting and graphic capabilities is currently being investigated. The behavioral, man-machine interaction implications of this effort extend beyond the scope of the current study.

VALIDATION

The question of model validity or validation was briefly touched upon in Chapter IV above. In that discussion, it was suggested that the problem of evaluating the validity of a "model" is not unique to simulation based analysis but rather must pervade any analytic framework or methodology. The unique aspects of

EXHIBIT 6.7

COMPUTER GENERATED RESPONSE SURFACE



formal operational modeling and simulation are that (1) the methodology compels explicit articulation of perceived systems relationships and (2) this operational articulation constitutes both a vital vulnerability to challenge and a vehicle for explicitly evaluating the significance and implications of validity questions.

All too often the question of "model" validation is implicitly ignored or minimized when complex systems relationships are analyzed through the application of closed analytic optimization models. In this context the efficiency of mathematical algorithms or solution techniques may be emphasized at the expense of verifying that the solution is meaningfully addressed to the problem. Many of the same problems of parameter estimation, abstraction and aggregation encountered in simulation based studies are equally significant and troublesome to closed analytic techniques, but may be less obvious and open to challenge when imbedded in an eloquent optimization algorithm. The necessity for validity testing, therefore, is not unique to the simulation methodology, but often is more explicitly stressed and meaningfully confronted in that context.

Numerous philosophies and techniques of model validation have been set forth in the literature over the past decade. The contributions by Naylor and Finger[9], Churchman[10], Fishman[11], and Cyert[12], are a representative sampling of this work which has ranged from considerations in the philosophy of science to rather sophisticated statistical techniques. If any pattern has emerged from these diverse efforts, it is only that the meaning of validation is far from clear and a great deal of work remains to be done.

Without reviewing specific state of the art proposals or summarizing the numerous quantitative techniques in this area, it may be useful to consider the role of various approaches to validation within the high level analysis process. Clearly, the concept of validation is, in some sense, related to the usefulness of a model in relation to some specified purpose or objective. Accordingly, meaningful validation criteria or validity testing techniques can only be defined in the context of these purposes or objectives.

Within the high level analysis process, formal modeling and simulation activities serve as a vehicle for pursuing a number of significant objectives. As outlined above, the modeling process (1) provided a common basis for understanding and communicating systems relationships among diverse participant groups, (2) generated a flexible adaptive systems representation for heuristically exploring perceived problems and decision alternatives and (3) developed an operational measurement base capable of evaluating the impact of decision alternatives at a higher systems level. Each of these objectives and their many corollaries demand something different from validation and must be approached appropriately.

Throughout the conceptual systems modeling process observed systems activities and relationships were correlated with operating personnel interviews to generate an initial micro modeling framework. These systems representations were then reviewed with supervisory management to verify their completeness and accuracy and extend the framework to incorporate interdepartmental relationships. This perspective in turn was examined and extended with divisional management personnel, again to verify the integrity of the framework and incorporate the broader perceptions and experience developed at this higher systems level. The integrated framework was further reviewed with senior systems staff representatives and consultants to the firm in order to verify the total structure of the conceptual model and confirm or qualify line management perceptions.

This line of verification, roughly corresponding to Naylor and Finger's[13] concept of "rationalism," constitutes an essential level of validation in relation to the first and second objectives set forth above. It was stressed in preceding chapters that significant pay-offs or benefits accruing from the high level analysis derive from the process of model development and the utility of the model as a conceptual vehicle quite apart from its capability as a simulator. In relation to this purpose, then, conceptual validation in the sense of verifying perceived systems relationships in an essential and appropriate function.

As the conceptual system model is documented in terms of logical flow charts, additional aspects of validation including an evaluation of the abstraction process and the maintenance of symbolic correspondence with the conceptual model must be developed. These dimensions of the validation process may impact significantly on the contribution of the model as a common framework for structuring and comprehending diverse management experience and perceptions.

Verification of the translation from the logical flow charts to formal computer-based programs often is impeded by a communication gap between management understanding of the system and technician understanding of the programming environment. This problem is particularly significant in the context of the high level analysis where diverse management personnel must interact heuristically with the operationalized model and participate in shaping its evolution over time. The use of high level simulation compilers and segmented programming techniques may contribute substantially to the resolution of this problem by drawing management participation and verification further into the operationalization process.

Empirical validation of the operationalized simulation model can be pursued through a hierarchy of levels which, again, must be related to the purpose or objectives underlying the modeling effort. Experimental simulation runs with simplified test data may be useful in evaluating the stability of the model and revealing any internal inconsistencies, incomplete logical specifications, and gross discrepancies between actual and modelled system behavior. Extended experimental runs with ranging of parameter specifications and data inputs generates a basis for evaluating the heartiness of the model and the completeness of model representations relating to non-typical circumstances such as high volume periods, processing errors or unusual combinations of events. These experimental results also can be interpreted as sensitivity tests on parameter estimates, data precision, decision rules and the level of aggregation in model representations. Evaluation of these sensitivities may suggest a need for expanding the data base, data analysis activities or systems modeling efforts in relation to critical areas.

The usefulness of the model in terms of comprehending systems relationships and behavior can be appraised to some degree through numerous variations of Turing tests. This approach involves examination of selected outputs or measures of simulated system behavior by "experts" intimately familiar with the actual system to identify any apparent differences in behavior. The continuing involvement of management personnel in the high level analysis process provides an effective vehicle for tests of this nature on both a formal and informal basis.

Application of the operationalized system model as a measurement system as well as a conceptual model demands more extended validity testing of the degree of correspondence between actual and simulated system behavior. It is at this level of measuring goodness of fit, most often in relation to retrospective predictions, that formal statistical techniques are brought to bear on the validation process. In this context, various statistical tests can be applied to measure goodness of fit or the degree of correspondence at numerous levels depending upon the purpose of the simulation.

In relation to the dynamics of system behavior, it may be of primary significance to measure the ability of the simulator to identify the form of dynamic interactions over time, such as dampening oscillation, decaying growth or unstable feedback configurations. At a more demanding level, it may be useful to evaluate the performance of the simulator in predicting the timing and direction of turning points in key time series. Beyond this, measures of absolute correspondence in amplitude as well as direction of fluctuations in key variables may be applied. In other contexts, the correspondence of average values or point measurements of simulated variables to parallel actual system measures may be of primary significance. Statistical tests of varying degrees of sophistication have been devised to support these inquiries among others, but their general relevance or usefulness clearly depends upon the nature of the modeling effort and the purpose of the simulation.

Evaluation of the simulator's ability to make prospective predictions or forecasts involves difficult philosophical as well as operational measurement problems. Considerations of the extent to which model predictions may be testable, self fulfilling, predicated upon existing perceptions or useful in relation to specific decision processes have been variously treated in many fields of literature, resulting in few definitive conclusions or generalizable methodologies. While these difficulties suggest an important need for further research, the motivation and implications of this need extend far beyond simulation based analysis.

SUMMARY

This chapter, together with the appendix immediately following, has examined significant elements or dimensions of the operational application of the high level analysis process with particular reference to the field study introduced in Chapter V. An important overall conclusion from this examination is that significant benefits or contributions from the high level analysis accrue through systematic application of the methodology quite apart from direct application of the computer-based simulator.

While a number of problem areas, including the "heaviness" of large scale computer-based modeling and conceptual as well as operational difficulties in validating the simulator were identified, these problems appeared to be resolvable in the context of an advanced management environment and did not significantly constrain the analysis process.

Broad ranging application of the computer-based system model as a measurement system will be examined in the following chapter in the context of further implications and extensions. Meaningful evaluation of a continuing management involvement and heuristic interaction with the computer based system model over time necessarily involves organizational and behavioral questions which can only begin to be identified at this time. Accordingly, these questions will be associated with areas for further research with some tentative indication of the potential direction and contribution of these efforts.

APPENDIX

COMPUTER-BASED SYSTEM MODEL DOCUMENTATION

TEMPORARY SYSTEM VARIABLES

COMM — Two words (used by clock)

Event notice schedules in clock routine to call endogenous event, COMM, to process orders through payroll.

CREDT — Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, CREDT, to process orders through credit review.

DAYID — Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, DAYID, to update payday counter.

DOVAL — Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, DOVAL, to process orders through computer validation run.

EDIT — Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, EDIT, to process orders through editing.

EROUT — Four words

Contents:

Word	Attribute	Mode	Explanation
1-2	---	---	Used by clock
3	ERRID	I	Address of ORDER with error condition being processed
4	---	---	Not used

Event notice scheduled in clock routine to call endogenous event, EROUT, to resubmit order with corrected error conditions to keypunch.

KEYP Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, KEYP, to process orders through keypunch.

ORDER Two words

Contents:

Word	Fraction	Attribute	Mode	Explanation
1	1/2	S(Queue name)	I	Address of next order in queue; used for list processing
	3/4	BRNUM	I	Branch number of order (consecutive branch numbers, 1-92)
	4/4	ECODE	I	Indicates type of error condition encountered, if any.
2	1/2	CLOCK	F	Available to store time for for computation of processing delays etc.; not presently used.
	3/4	CCODE	I	Indicates credit status of order: 0 = pass 1 = computer screen failure 2 = substandard rep. 3 = branch request 7 = throwback
	4/4	---	---	Not used

OUTPT Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, OUTPT, to periodically write counters to output tape.

MAIL Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, MAIL, to read in new orders from input tape.

TERMS Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, TERMS, to process orders through terms.

SCHL1 Four words

Contents:

Word	Attribute	Mode	Explanation
1-2	---	---	Used by clock
3	NITE	I	Differentiates day and night shifts in editing department. 0 = day shift 1 = night shift
4	---	---	Not used

Event notice scheduled in clock routine to call endogenous event, SCHL1, to control start up time, quitting time and lunch break in editing; also allocates man hours between day and night shifts.

SCHL2 Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, SCHL2, to control start up time, quitting time and lunch break in keypunch.

SCHL3 Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, SCHL3, to control start up time, quitting time and lunch break in credit review.

SCHL4 Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, SCH14, to control start up time, quitting time and lunch break in payroll.

SCHL5 Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, SCHL5, to control start up time, quitting time and lunch break in terms.

SCHL6 Two words (used by clock)

Event notice scheduled in clock routine to call endogenous event, SCHL6, to control mail pick-up times for new orders.

PERMANENT SYSTEM VARIABLES

Name(dimension)	Array Number	Mode	Explanation
BEDIT	54	F	Counter used for computations in SCHL1.
BEGIN(5)	49	F	Start-up times for operating departments: 1 = Editing 2 = Keypunch 3 = Credit Review 4 = Payroll 5 = Terms
BRNCH	1	E	Permanent entity set at number of branches = 92.
BRP(92)	60	F	Branch request orders as a percent of total orders for each branch; derived from credit review data.
CODE7(92)	21	I	Counter for Credit Review throwback orders for each branch.
COL1	3	E	Permanent entity set at 40 to control STIX(40,6).
COL2	4	E	Permanent entity set at 6 to control STIX(40,6).
COL3	5	E	Permanent entity set at 10 to control HOTDA(10).
CRCP(92)	43	F	Credit review ceiling rejection rate for each branch; derived from credit review data.
CRRP(92)	42	F	Rejected computer credit screen failures before throwbacks as a percent of total computer credit screen failures for each branch; derived from credit review data.
CSFP(92)	41	F	Computer credit screen failures as a percent of total orders for each branch; derived from credit review data.

CYCLE	55	F	Days to next working day. CYCLE was originally used to skip days for weekends; presently weekends are ignored and CYCLE remains equal to 1.
DAYS	2	E	Permanent entity set a number of paydays = 5.
DELAY	47	F	Step function random look up table determines delay in resubmitting order with error condition; based on hypothetical data.
DEPTS	6	E	Permanent entity set a number of operating departments = 5.
ERROR	40	I	Step function random look up table determines existence and nature of error conditions; based on hypothetical data. Presently nature of error condition is irrelevant; all delays due to errors are determined by DELAY.
FAIL(92)	23	F	Counter for orders rejected in Credit Review including throwbacks but excluding branch request and substandard rep. orders for each branch.
FBACH	34	I	Address of first ORDER in the queue, BACH.
FERR1	24	I	Address of first ORDER in the queue, ERR1.
FERR2	26	I	Address of first ORDER in queue ERR2.
FIRST(5)	15	I	Holds pointers to first ORDERs in "holding queues"(for each payday) which hold the contents of QUE6(i) during validation. This establishes a cut off for terms and credit review transactions entering a given validation and merges QUE6(i)(for each branch, i = 1,92) to payday queues.
FQUE1(5)	7	I	Address of first ORDER in the queue, QUE1(i) (for each payday, i = 1,5)
FQUE2	28	I	Address of first ORDER in the queue, QUE2.
FQUE3	30	I	Address of first ORDER in the queue, QUE3.
FQUE4(5)	9	I	Address of first ORDER in the queue, QUE4(i) (for each payday, i = 1,5)
FQUE5(5)	11	I	Address of first ORDER in the queue, QUE5(i) (for each payday, i = 1,5)

FQUE6(92)	17	I	Address of first ORDER in the queue, QUE6(i) (for each branch, i = 1,92)
FQUE7(92)	19	I	Address of first ORDER in the queue, QUE7(i) (for each branch, i = 1,92)
FQUE8(5)	14	I	Address of first ORDER in the queue, QUE8(i) (for each pay day, i = 1,5)
FVAL	32	I	Address of first ORDER in the queue VAL.
HOTDA(10)	56	I	Contains the day of the work week (1 to 5) starting with the current day and running for 10 work days. Thus, if Editing is processing orders two paydays ahead, they are working on HOTDA(3) orders.
ID(6)	52	I	Addresses of event notices: 1 = EDIT 2 = KEYP 3 = CREDT 4 = COMM 5 = TERMS 6 = MAIL These addresses are required to cancel and reschedule event notices to control working hours and lunch breaks.
IDENT(92)	46	I	Contains actual branch numbers serving as a cross reference to consecutive branch numbers used for computational purposes.
INBCH	37	I	Counts number of ORDERs in the queue, BACH, created in Editing. Batches are transferred to keypunch when INBCH reaches 100.
LAST (5)	16	I	Holds pointers to last ORDERs in "holding queues" (for each payday) which hold the contents of QUE6(i) during validation. This establishes a cut off for terms and credit review transactions entering a given validation and merges QUE6(i) for each branch, i = 1,92) to payday queues.
LBACH	35	I	Address of last ORDER in the queue, BACH.
LERR1	25	I	Address of last ORDER in the queue, ERR1.
LERR2	27	I	Address of last ORDER in the queue, ERR2.
LQUE1(5)	8	I	Address of last ORDER in the queue, QUE1(i) (for each payday, i = 1,5)
LQUE2	29	I	Address of last ORDER in the queue, QUE2.
LQUE3	31	I	Address of last ORDER in the queue, QUE3.

LQUE4(5)	10	I	Address of last ORDER in the queue, QUE4(i) (for each payday, i = 1,5)
LQUE5(5)	12	I	Address of last ORDER in the queue, QUE5(i) (for each payday, i = 1,5)
LQUE6(92)	18	I	Address of last ORDER in the queue, QUE6(i) (for each branch, i = 1,92)
LQUE7(92)	20	I	Address of last ORDER in the queue, QUE7(i) (for each branch, i = 1,92)
LQUE8(5)	13	I	Address of last ORDER in the queue, QUE8(i) (for each payday, i = 1,5)
LUNCH(5)	63	F	Time for beginning lunch break in each operating department: 1 = Editing 2 = Keypunch 3 = Credit Review 4 = Payroll 5 = Terms
LVAL	33	I	Address of last ORDER in the queue, VAL.
PAIR1	48	E	Permanent entity set at 14 to control random look up arrays in the function RATE1.
PAYDA(92)	39	I	Contains the payday for each branch in consecutive order.
PROB1(14)	57	F	Contains cumulative probabilities for the 14 ranges of the random look up table in the function, RATE1, derived from Editing data.
QUIT(5)	50	F	Quitting times for each of the operating departments: 1 = Editing 2 = Keypunch 3 = Credit Review 4 = Payroll 5 = Terms
RATE(6)	51	F	Order processing rates for each of the operating departments in department days per order: 1 = Editing 2 = Keypunch 3 = Credit 4 = Payroll 5 = Terms The processing rates are calculated in the exogenous event routine, RATES, which reads the processing rate (in minutes per order per operative) and the number of operatives

			for each department from the exogenous event file. New data can be read in at any time by calling RATES. The processing rate in Editing presently is being determined independently in SCHL1 as a random function calculated by the function RATE1. Except for Editing, all data is hypothetical.
RBRP(92)	62	F	Rejected branch request orders as a percent of total branch request orders for each branch; derived from credit review data.
RSSP(92)	61	F	Rejected substandard rep. orders as a percent of total substandard rep. orders for each branch; derived from credit review data.
SSP(92)	59	F	Substandard rep. orders as a percent of total orders for each branch; derived from credit review data.
STIX(40,6)	38	I	Counter matrix for accumulating order processing data by payday throughout the system. Elements of this matrix are periodically written onto the output tape by the endogenous event routine OUTPT. See separate schedule for detailed definition of each element.
TDP(92)	45	F	Orders not cleared and ultimately deleted in Terms as a percent of total orders sent to Terms for each branch. This data is hypothetical and may be inappropriate for the model.
TEDIT	53	F	Counter used for computations in SCHL1.
TERM(92)	44	F	Orders sent to Terms as a percent of total orders for each branch. This is hypothetical data.
TOTAL(92)	22	F	Counter for total orders sent to Credit Review for each branch.
VALNO	36	I	Validation run number(1,2 or 3) read from exogenous event file by INVAL which initiates the validation process.
VALU1(14)	58	F	Contains values (processing rates in Editing) for the 14 ranges of the random look up table in the function, RATE1; derived from Editing data.

EXOGENOUS EVENT ROUTINES

ENDIT Exogenous event ENDIT is scheduled on the exogenous event file at a time corresponding to the end of the simulation. Its only function is to stop the simulation; therefore, it is the last routine executed in the program.

INVAL Exogenous event INVAL is scheduled on the exogenous event file at a time corresponding to the cut-off for orders and transactions entering a given validation run. INVAL is presently scheduled at 11:30, 17:30 and 23:30 on each day of the simulation.

Primary Functions:

1. Transfers orders from QUE3 (orders completed in Keypunch) to VAL (orders to be processed in validation) through SUBROUTINE TRANSET.

2. Creates event notice to call endogenous event DOVAL, which processes orders through validation, and schedules DOVAL to occur in 3.5 hours.

3. On the third validation of each day (validation run number is read by INVAL from exogenous event file) INVAL calls SUBROUTINE BALBRNCH which executes the "branch balancing" process in Credit Review for orders to be paid the next day.

4. Adjusts appropriate output counters (see STIX) to reflect the flow of orders.

5. Transfers orders for QUE6(i)(orders previously cleared in Credit Review and Terms) to "holding queues" which will in turn be transferred to QUE5(i)(Payroll) by DOVAL in 3.5 hours.

RATES Exogenous event RATES can be scheduled on the exogenous event file at any time during the simulation to read in new processing rates and staff complements for each of the five operating departments.(except Editing which is a special case; see endogenous event SCHL1) RATES is presently scheduled only once, at the beginning of the simulation.

Primary Functions:

1. Reads number of operatives and processing rate (in minutes per order per operative) for each department from exogenous event file. If the number of operatives is zero for a given department subsequent computations are deleted for that department.

2. Computes a processing rate in department days per order (which is compatible with the SIMSCRIPT clock) for each department and stores this value in RATE(i)(i = 1,5)

START Exogenous event START is executed only once, at the beginning of the program. START sets up the event notices which control the endogenous operation of the simulation.

Primary Functions:

1. Creates event notices for all endogenous events except DOVAL (created by INVAL) and EROUT (created by EDIT.)

2. Stores addresses of event notices representing operating departments in ID(i) for subsequent control by corresponding SCHL routines.

3. Schedules OUTPT and SCHL routines in clock to initiate endogenous operations of the simulation.

ENDOGENOUS EVENT ROUTINES

COMM Endogenous event COMM represents the processing of orders through Payroll.

Primary Functions:

1. Removes hot payday order from QUE5(i), counts orders processed, and destroys ORDER to return its two words to available core.

2. Reschedules COMM at current time plus RATE(4).

CREDT Endogenous event CREDT represents the processing of orders through Credit Review.

Primary Functions:

1. Removes first order from most imminent non-empty payday queue of QUE4(i) beginning with next day's payday.

2. References CCODE or ORDER to determine credit status: (1) Computer credit screen failure, (2) substandard rep. or (3) branch request.

3. Determines if order will be accepted or rejected by comparing random number with appropriate branch element of CRRP(i) for screen failures), RSSP(i) for substandard rep. orders) or RBRP(i)(for branch request orders).

4. Files accepted orders in QUE6(i)(by branch) which will be transferred to QUE5(i) in Payroll in the next validation run.

5. Files rejected credit screen failures in QUE7(i)(by branch) which will be used by SUBROUTINE BALBNCH for "balancing branches" at the end of their respective pay weeks. Destroys rejected substandard rep. orders and rejected branch request orders to return their words to available core.

6. Adjusts appropriate output counters (see STIX) to reflect the flow of orders.

7. Reschedule CREDT at current time plus RATE(3).

DAYID Endogenous event DAYID is called once each simulated day to update HOTDA(i)(i = 1,10) HOTDA(i) contains the day of the work week (1 to 5) beginning with the current day and running for 10 work days.

Primary Functions:

1. Updates HOTDA (i) by shifting each element foreward one place and transferring HOTDA(i) to HOTDA (10)

2. Defines CYCLE at 1.0. Originally CYCLE was set at 3.0 on Fridays to skip weekend days, but leave them available. Presently, weekends are deleted and CYCLE remains at 1.0.

3. Reschedules DAYID at current time plus one day.

DOVAL Endogenous event DOVAL represents the processing of orders through computer validation. The event notice for DOVAL is created and scheduled in the exogenous event, INVAL.

Primary Functions:

1. Tests all new orders and resubmits in the queue, VAL, for error conditions by reference to random look up table, ERROR. Orders with error conditions are filed in queue, ERR1, processed by Editing. ECODE of ORDER is set to indicate type of error encountered.

2. Tests all new orders and resubmits in the queue, VAL, for credit status of (1) credit screen failure, (2) substandard rep. or (3) branch request by comparing a random number with the corresponding values of the tables (1) CSFP (1), (2) SSP(i) or BRP(i) for the appropriate branch, i. CCODE of ORDER is set to indicate credit status determined.

3. Tests all orders and resubmits in the queue, VAL, for terms problems by comparing a random number with the value of TERM(i) for the appropriate branch, i. Orders with terms problems are filed in the queue, QUE8(i) to be processed in Terms.

4. Files orders with credit problems, not already transferred, to Terms, in the queue, QUE4(i) to be processed in Credit Review.

5. Files accepted orders in the queue, QUE5(i) to be processed by Payroll.

6. Transfers orders previously cleared in Terms and Credit Review from "holding queues" to the queue, QUE5(i) to be processed by Payroll.

7. Adjusts appropriate output counters (see STIX) to reflect the flow of orders.

8. Destroys event notice DOVAL to return its two words to available core.

EDIT

Endogenous event EDIT represents the processing of orders through Editing.

Primary Functions:

1. Removes first error condition order (if any) from the queue, ERR1. Determines processing delay due to error condition by reference to random look up table DELAY. Creates event notice EROUT, stores the address of ORDER in ERRID of EROUT, and schedules EROUT in the clock at the time when the error condition will be resolved. When EROUT is ultimately called, the error condition order will be transferred to Keypunch as a resubmit (see endogenous event EROUT.)

2. Removes first new order from most imminent non-empty payday queue of QUE1(i) beginning with day after tomorrow's payday.

3. Files order in the queue, BACH, and increments counter INBCH. When INBCH reaches 100, the entire batch is transferred to the queue, QUE2 to be processed in Keypunch. INBCH is then set to zero.

4. Adjusts appropriate output counters (see STIX) to reflect flow of orders.

5. Reschedules EDIT at current time plus Rate(1).

EROUT

Endogenous event EROUT is called by an event notice created and scheduled in EDIT. EROUT transfers an error condition order (the address of ORDER is obtained from ERRID of EROUT) to the queue, ERR2, to be processed as a resubmit in Keypunch. The lapse of simulated time before an error condition order is transferred to ERR2 is determined as a random function (see DELAY) to represent the time required to correct the error condition.

KEYP

Endogenous event KEYP represents the processing of orders through Keypunch.

Primary Functions:

1. Transfers first error condition order, if any, from the queue, ERR2 to the queue QUE3 to be processed in the next validation run.

2. Transfers first new order from the queue, QUE2, to the queue, QUE3, to be processed in the next validation run.

3. Adjusts appropriate output counters (see STIX) to reflect the flow of orders.

4. Reschedules KEYP at current time plus RATE(2).

MAIL Endogenous event MAIL represents the receipt of new orders in Cashiering. Since the order entry data was created at the end of the Cashiering process, new orders enter the simulator at the end of the Cashiering process and no Cashiering department is represented.

Primary Functions:

1. Reads number of new orders received for each branch during the current period (half hour) from the input tape.

2. Creates a temporary entity, ORDER, for each new order received.

3. Stores consecutive branch number (1 to 92) of originating branch in BRNUM of ORDER.

4. Files orders in the appropriate payday queue, QUE1(i), to be processed by Editing.

5. Adjusts appropriate output counters (see STIX) to reflect the flow of orders.

6. Reschedules MAIL at current time plus one half hour.

OUTPT Endogenous event OUTPT writes selected output counters (see STIX) to the output tape and reinitializes the output counter every half hour of simulated time.

SCHL1 Endogenous event SCHL1 controls the processing rate and working hours in Editing.

Primary Functions:

1. Determines daily budgeted man hours in Editing as yesterday's volume plus current backlog divided by average processing rate in orders per man hour. (derived from Editing data.)

2. Allocates budgeted man hours between day and night shifts on the basis of a linear regression fit to Editing data.

3. Determines processing rate for day and night shifts as a random function based on Editing data (see function, Rate1).

4. Stops processing in Editing for 45 minute lunch break beginning at time stores in LUNCH(1). Stops processing in Editing at end of night shift (QUIT(1)) and restarts processing at beginning of day shift (BEGIN(1)).

SCHL2 SCHL3 SCHL4 SCHL5 — These endogenous event routines control the working hours in Keypunch, Credit Review, Payroll and Terms, respectively, and are essentially identical.

Primary Functions:

1. Stops processing in operating departments for 45 minutes lunch break at time stored in LUNCH (i)(i = 2,5).

2. Stops processing in operating departments at end of work day stored in QUIT(i)(i = 2,5) and restarts processing at beginning of work day stored in BEGIN(i)(i = 2,5).

SCHL6 — Endogenous event SCHL6 controls the running hours for endogenous event MAIL which reads in new orders every half hour from 7:15 a.m. to 6:45 p.m. with no lunch break. SCHL6 stops MAIL processing at 19:00 hours and restarts MAIL processing at 7.25 hours daily.

TERMS — Endogenous event TERMS represents the processing of orders through Terms.

Primary Functions:

1. Removes first order from most imminent non-empty payday queue of QUE8(i) beginning with the next day's payday.

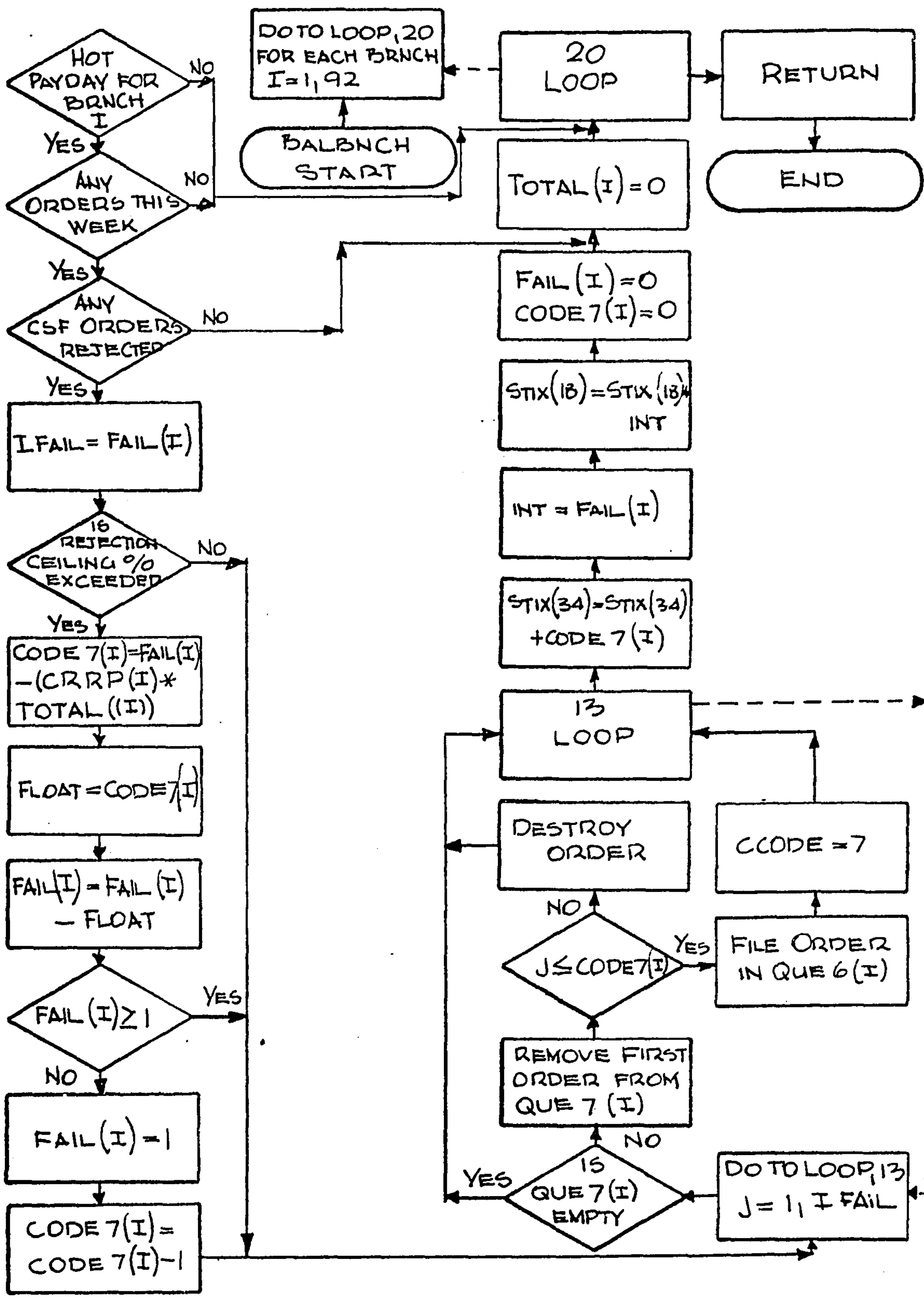
2. Determines if terms condition will result in deletion of order by comparing a random number with the value of TDP(i) for the appropriate branch, i. If the order is deleted, it is destroyed to return its two words to available core. TDP(i) is based on hypothetical data and the concept of deleting orders in Terms may be inconsistent with the real system.

3. If the order is not deleted, CCODE of ORDER is evaluated to determine its disposition. If CCODE indicates a credit problem, the order is filed in the queue, QUE4(1), for processing in Credit Review. If no credit problem is present (CCODE = 0), the order is filed in the queue, QUE6(i), which will be transferred to Payroll in the next validation run.

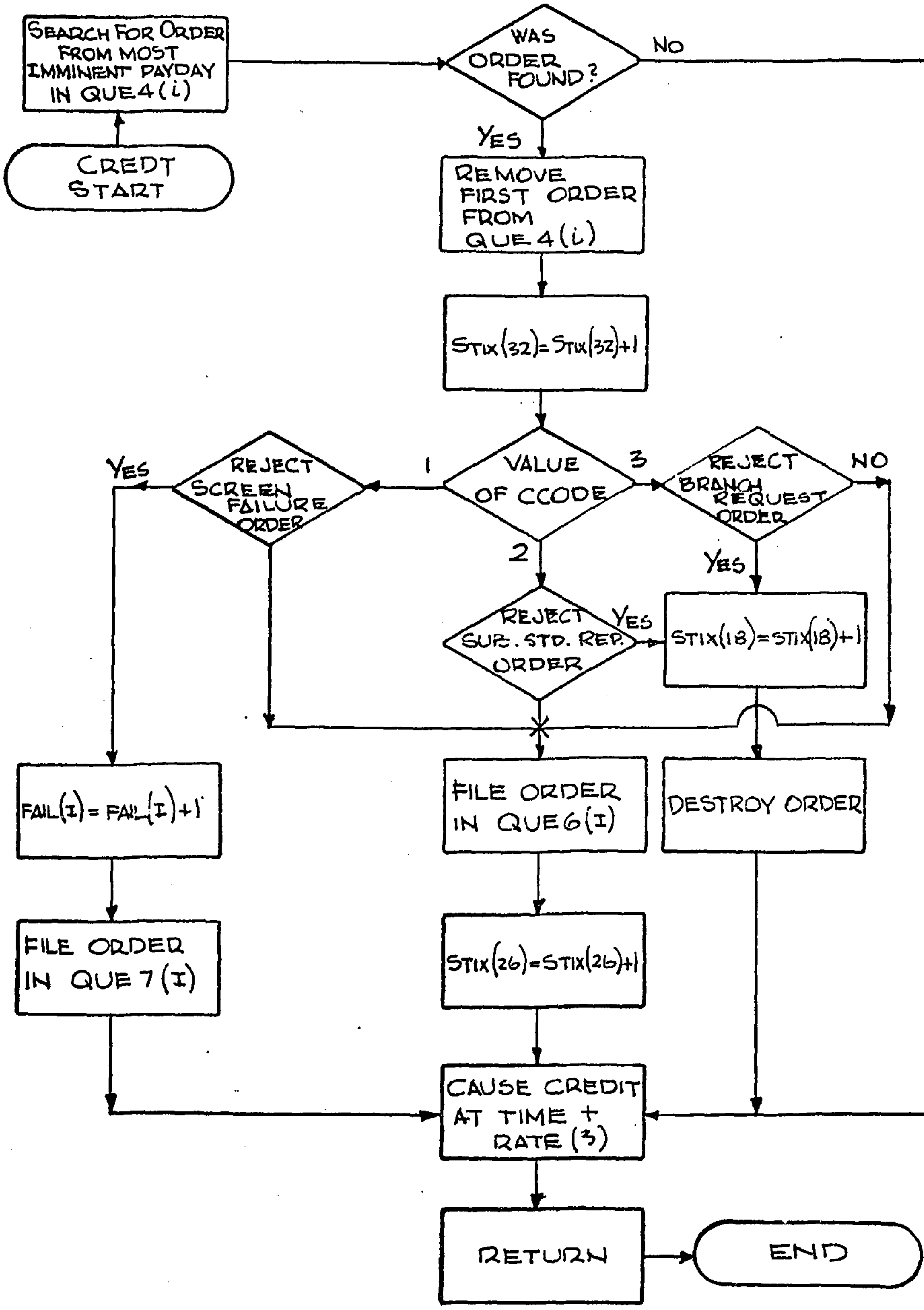
4. Adjusts appropriate output counters (see STIX) to reflect the flow of orders.

5. Reschedules TERMS at current time plus RATE(5).

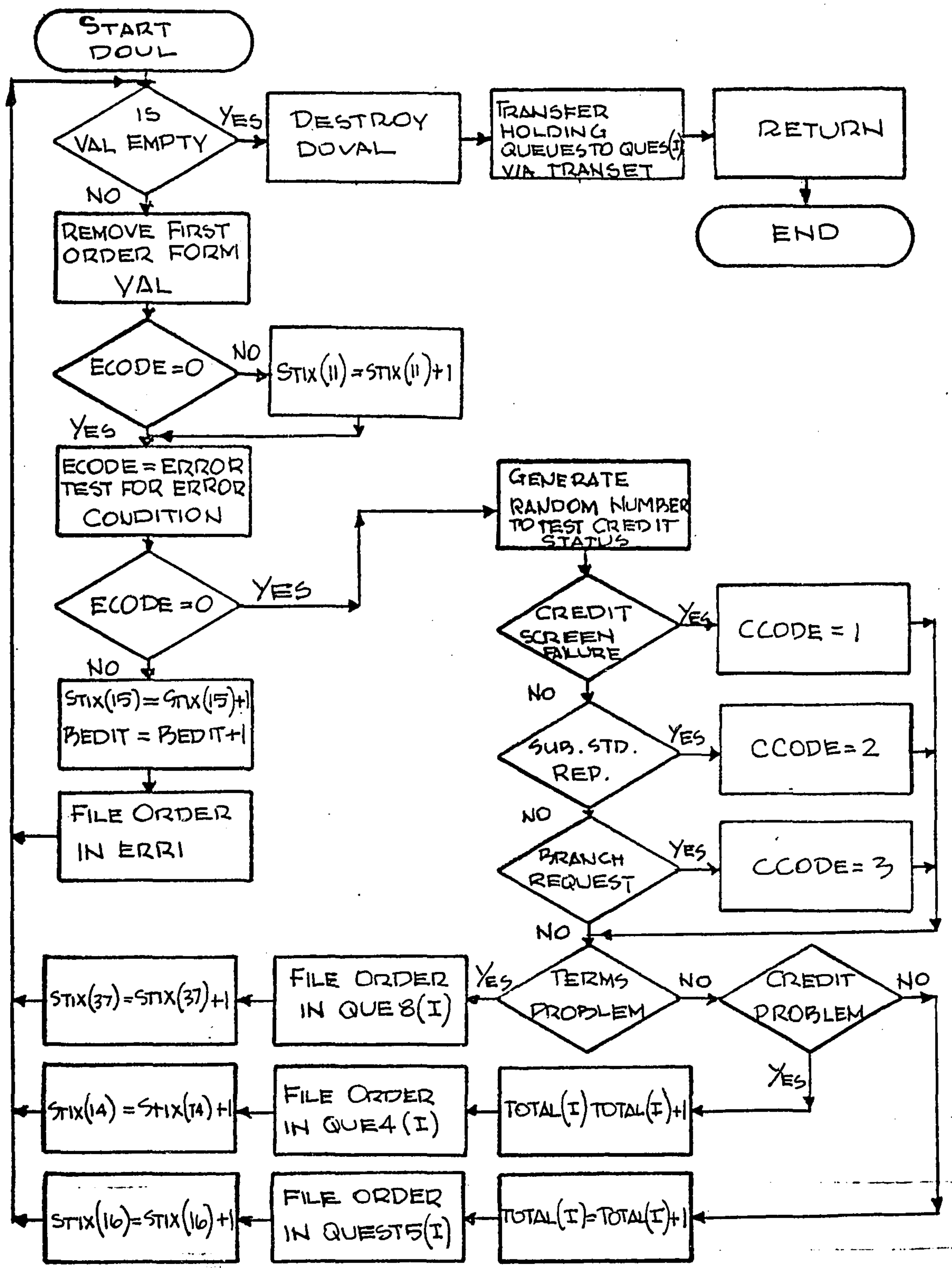
SUBROUTINE BALBNCH



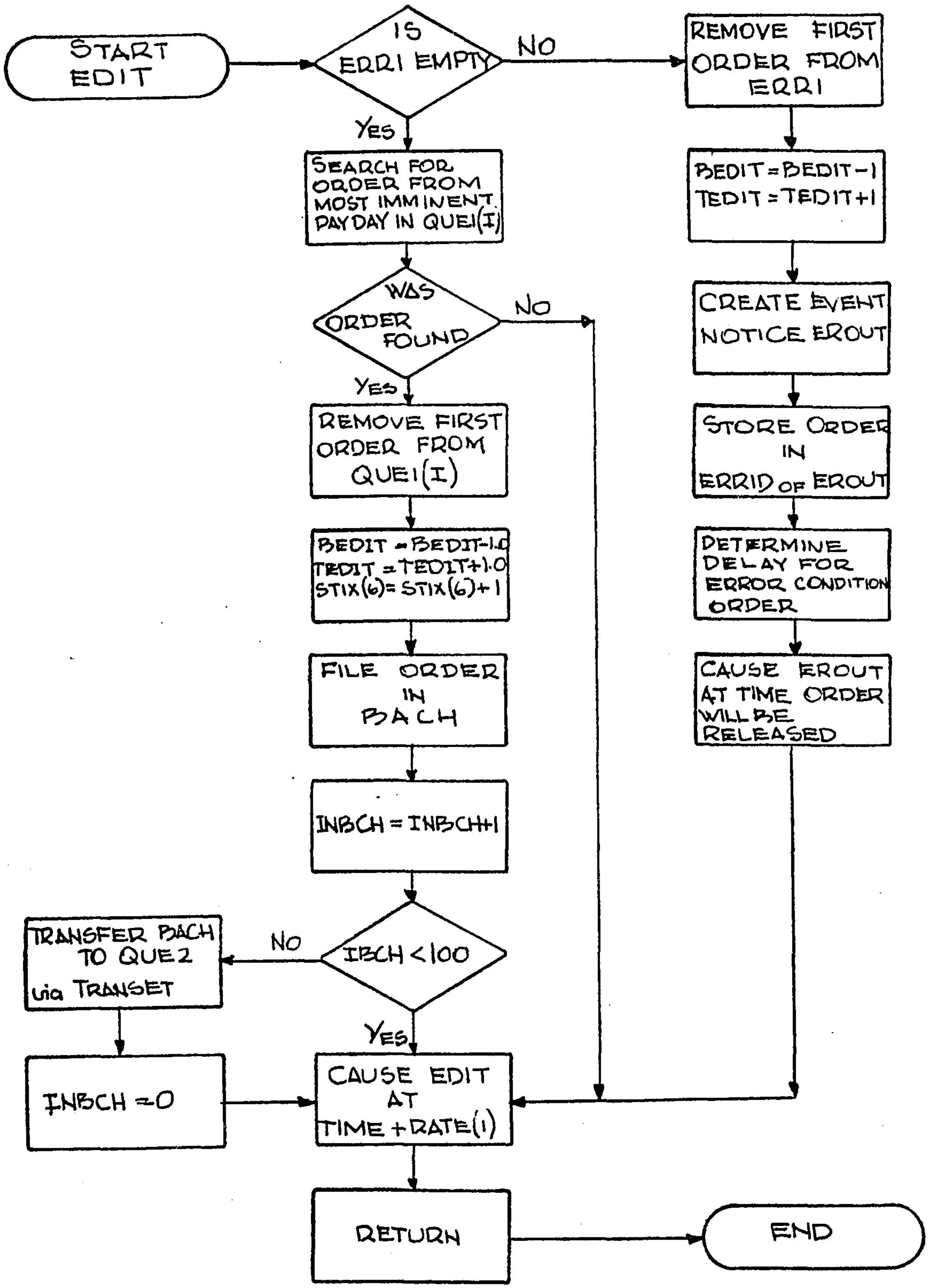
EXOGENOUS EVENT CREDT



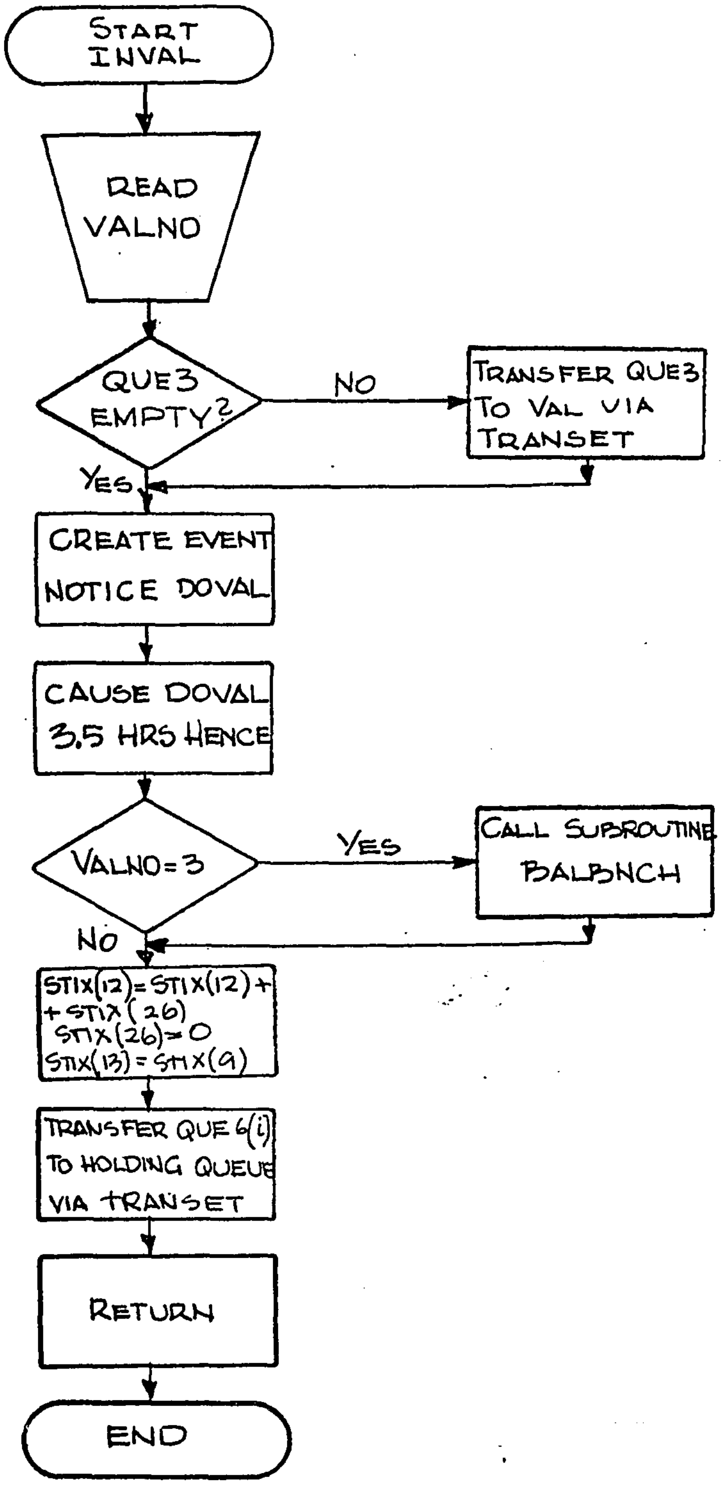
ENDOGENOUS EVENT DOVAL



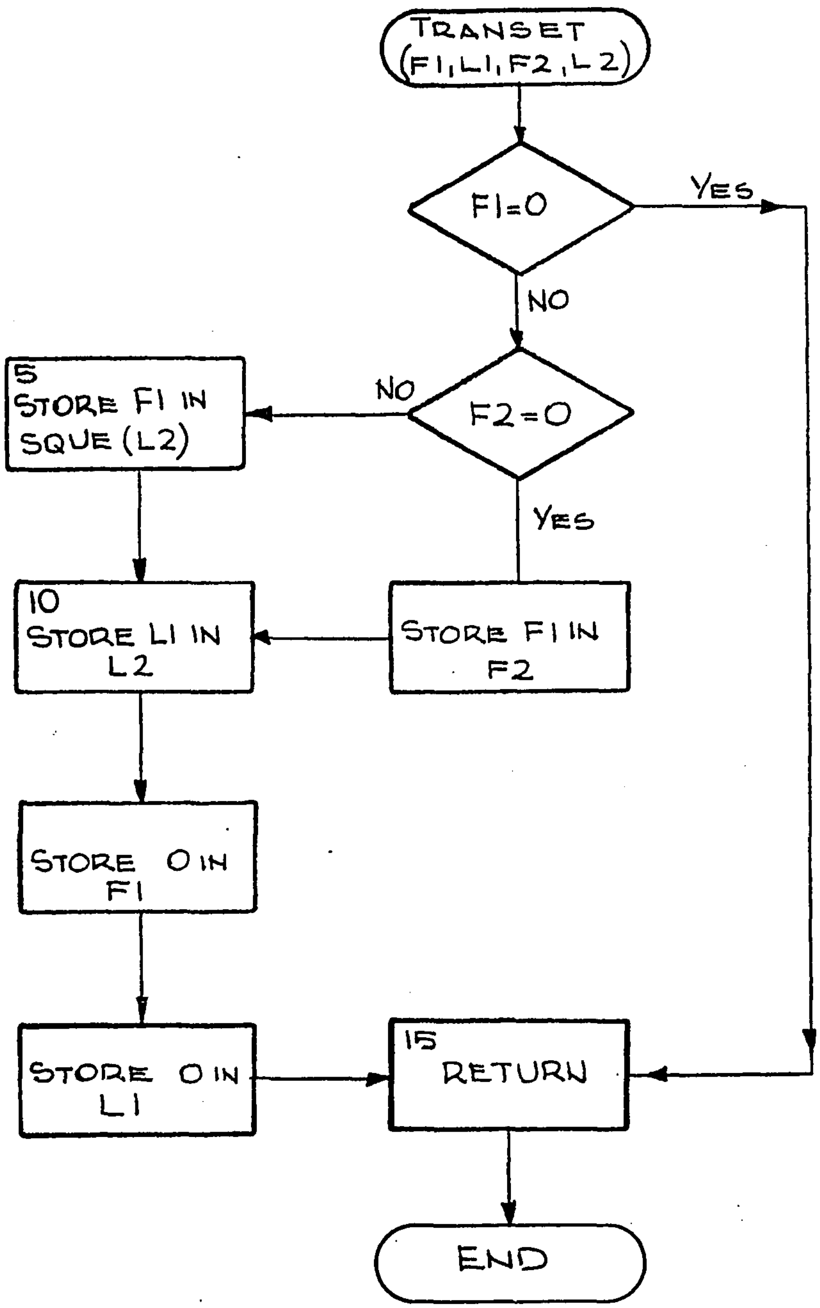
ENDOGENOUS EVENT EDIT



EXOGENOUS EVENT INVAL



SUBROUTINE TRANSET



VII. EXTENSIONS AND IMPLICATIONS

In the preceding chapters a conceptual framework based in the information systems analysis process and addressed to significant measurement problems in an advanced management environment was set forth. Crucial elements of this framework constituting a system model and an operational measurement system were further developed in relation to the objectives of the analysis process and the unique requirements and resources of the advanced management environment. The application of large-scale computer-based modeling and simulation as a methodological basis for these elements of the analysis process was examined at both a conceptual and an operational level.

The extended field study discussed in Chapters V and VI was undertaken to provide a vehicle for exploring and evaluating significant dimensions of the proposed framework of analysis in a live context and more meaningfully relate crucial aspects of the analysis process to real world problems and requirements. The scope of the field study was rather ambitious in magnitude of analysis requirements, breadth of objectives and time horizon. This expanded scope was deemed to be appropriate to the exploratory objectives of the field study, but necessarily implied that the full implications and ultimate contribution of the field study analysis process could not be incorporated in the time frame of this project. In relation to these constraints, the following sections identify and tentatively evaluate a number of areas representing significant potential extensions and directions for further inquiry.

MEASUREMENT APPLICATIONS

The role of computer-based modeling and simulation in the high level analysis has been discussed above primarily in terms of the methodology or process of information systems analysis rather than the structuring of specific information flows or measurement requirements. This emphasis reflects both the underlying need for an operational framework of analysis and the systems analysis foundation necessary to meaningfully define information requirements.

While examination of the analysis methodology constituted the major thrust of the field study project, a number of significant information requirements and corresponding measurement applications were identified and tentatively explored. Five types or categories of information requirements examined in this context are briefly discussed below. These examples are neither exhaustive nor fully developed, but rather are set forth to reflect the nature and range of relevant simulation based measurements.

1. Resource Requirements

Short-term budgeting of operating resource requirements in a highly interdependent systems context such as that encountered in the field study project demands measurement capabilities not generally encompassed within conventional information systems. The impact of resource budgeting decisions in a specific operating area upon other interdependent processes may be more significant than the direct impact of these decisions on costs or productivity in the specific area. Accordingly, a higher level measurement system capable of measuring the impact of local resource budgeting decisions upon related operating systems is required. The operationalized computer-based system model provides this capability.

In the context of the field study, manpower budgeting decisions in the cashiering and order editing areas not only affect processing costs in these areas, but much more significantly, influence volume variations and processing delays in subsequent sequential processing systems. In other words, some over staffing (on a cost per order processed basis) in these initial processing operations may result in significant savings or processing efficiencies in subsequent operations. Relevant ranges of staffing alternatives can be evaluated directly through the computer-based simulator to assess their impact on the total processing system. The results of these evaluations provide a basis for establishing resource requirements in each department in terms of broader systems criteria rather than potentially suboptimum local objectives. Furthermore, this approach through range testing reveals the sensitivity of total system performance to variations in specific parameters thereby highlighting crucial decision variables and identifying potential areas for more intensive investigation.

2. Capital Budgeting

Established capital budgeting evaluation models, including the discounted present value and internal rate of return techniques, require estimates of the incremental savings or contribution attributable to the addition or replacement of specific capital aspects. Again, the local impact of the asset acquisition decision in a specific operating area may be a poor reflection of the total incremental contribution in related systems, but the complexity of systems interactions may preclude meaningful measurement of these more significant indirect effects. The computer-based system model can be utilized to test the impact of capital budgeting alternatives at a higher systems level explicitly incorporating these complex systems interactions.

In relation to the field study project, the alternative of utilizing costly optical scanning equipment in place of manual keypunch operations illustrates a significant potential application in this area. The immediate, direct evaluation of processing costs associated with the mechanical and manual systems only begins to reflect the total marginal impact of the optical scanner. In fact, the impact of changes in processing rates and error rates upon subsequent operating systems may be substantially more significant than any direct cost savings in the data entry area. These indirect effects are difficult to appraise due to the complexity of volume variations, processing interdependencies and feedback flows associated with existing sequential processing systems. However, the computer-based simulator provides an operational vehicle for assessing these indirect effects across any relevant range of volume variations, processing constraints or other variables.

Furthermore, these simulation based measurements effectively highlight secondary constraints which may not be initially apparent. For example, faster processing in the order entry area may make orders available on a more timely basis in credit review only up to the point that constraints are encountered in the intervening computer-based credit screen system. As a result, potential payoffs from the optical scanner may be contingent upon relaxing these constraints by using more efficient computer systems. From a different perspective, the ultimate value of faster data entry could be measured by reducing data entry time to zero or some nominal duration in the simulator. The total potential contribution estimated from this inquiry would at least establish a boundary guideline for evaluating data entry alternatives or may suggest that other constraints must be pursued before it would be worthwhile to consider major data entry modifications.

3. System Design Alternatives

Closely related to the measurement applications discussed above, evaluation of numerous system design alternatives requires a broad systems perspective encompassing interactions among related operating areas. Whether new orders should be processed as received or on a differentiated priority basis, whether computer-based operating systems should be batch processed more frequently or converted to a real time system, and whether edit coding procedures should be supplanted by direct data entry represent significant inquiries implying information requirements not incorporated in the conventional information system.

The essential characteristics of these information requirements include the necessity to measure complex interactions among related operating systems and the need for heuristic specifications of measurement requirements as the evaluation process is pursued. In this context, discovering which questions are most significant in terms of total system performance may be more important and certainly should precede local refinements in operating procedures which may prove to be inappropriate or irrelevant. While simulation based measures involving tests of major changes in systems configurations suggest difficult problems of validity testing, even relatively imprecise estimates which are addressed to more relevant questions and lodged at an appropriate systems level may constitute a significant contribution.

4. Decision Criteria

The operational system model not only constitutes a measurement base for decision information requirements involving interactions among operating subsystems, but also provides a vehicle for evaluating the effectiveness of local decision models and decision criteria. As the organization evolves and functional areas are differentiated over time, local objective functions and decision criteria are established in relation to existing performance measures and perceived policies or constraints. These local objectives and decision criteria often become institutionalized through the formal internal reporting structure which may tend to reinforce and perpetuate established performance criteria without meaningfully questioning their contribution to broader system objectives.

Returning to the field study environment, order editing operations are monitored in relation to processing cost per order with the constraint that new orders must be initially processed through the editing operation by the second day before the commissioning date for each order. Beyond these criteria, it is recognized that the processing rate and error rate in the editing operation may have a significant impact on subsequent processing operations including the quality of credit review decisions, however, the relative value or priority of these criteria cannot be determined from existing information sources.

The computer-based simulator can be utilized to test the impact of ranges of order editing processing rates and error rates as well as alternative decision rules for assigning processing priorities in the context of modeled relationships, feedback flows and interdependencies. These tests provide a basis for assessing the significance of new dimensions to existing decision processes and new elements in local objective functions defined in terms of broader system criteria. Ideally, the value of alternative error and processing rates could be derived in terms of a decision response surface related to the processing costs required to achieve each combination of results. Short of this, the simulation based analysis would at least reveal the relative significance of alternative decision criteria and suggest promising directions for further inquiry.

5. Policy Alternatives

From a broader perspective, a number of policy specifications identified and described in Chapter V above were seen to impact in a complex fashion across many operating systems and decision processes in the organization. Among these policy specifications were the credit rejection ceilings, the two stage credit evaluation, the operational independence of sales branches and the weekly commissioning structure with rigid processing cutoff requirements. These policies were established over time in response to diverse perceived problems and while it is recognized that they constitute major constraints on existing operating systems with substantial cost implications, the real impact of these constraints cannot be meaningfully analyzed through existing information systems capabilities.

Alternative or relaxed policy specifications can be evaluated through the computer-based simulator in terms of their impact on existing operating systems. For example, alternative commissioning policies including a provision for additional days between the order receipt and commissioning cutoffs or processing of all orders as received with no commissioning deadline would significantly affect resource budgeting problems throughout the sequential processing operations and provide more time for the credit evaluation decision. The operational system model provides a vehicle for directly evaluating these alternatives in the context of perceived systems relationships encompassing the various interactions and local constraints affected.

An interesting aspect of simulation based analysis at this level concerns the extent to which behavioral relationships can be explicitly incorporated in the operational system model. Crucial elements of the policy specifications identified above involve complex behavioral questions concerning sales motivation, the company's ability to attract and retain effective sales representatives and several aspects of customer relations. Given the perceived importance of these factors, relevant policy decisions must consider behavioral information or expectations regardless of whether these variables are incorporated in the formal system model.

In the field study project these factors were identified but explicitly excluded from the formal modeling effort. While a number of simulation based studies of behavioral interactions have been developed, these efforts have been rather conceptual in character with interesting implications but little direct application in the high level analysis process. At the state of the art in this area, direct incorporation of behavioral propositions in the formal system model may result in a degree of reduced confidence and qualification of conclusions that would substantially diminish the usefulness of the approach. Essentially then, the factors explicitly excluded from the system model must be weighed through judgment against simulation based measures in reaching related decisions. This is a familiar requirement in almost any decision making environment. An important extension has been achieved, however, in that many of the complex systems relationships which were previously in the realm of judgment can be more directly assessed through the operational system model.

MODELING EXTENSIONS

While the scope and objectives of the modeling process outlined in preceding chapters were rather broad in conception and application, a number of significant extensions can be immediately identified. The appropriateness of specific extensions clearly depends upon the nature of the system, the state of the art in modeling perceived relationships and the cost benefit dimensions of expanding the analysis. As discussed above, the modeling process is heuristic and evolutionary over time. Initially coarse system representations may be used as a base for sensitivity tests suggesting worthwhile directions for further extensions and refinements. In general, the heaviness of the methodology together with the need for flexibility and adaptability over time argue strongly for the most simple explicit system model capable of effectively addressing relevant information requirements. The scope and sophistication of the model must be determined by the changing nature of information requirements, rather than the reverse.

In relation to the field study project, extensions encompassing sales branch and sales representative behavior in generating and submitting product orders would incorporate many significant determinants of volume variations within the formal model rather than interpreting these factors as constraints or variables exogenous to the analysis. Similarly, other environmental factors including product and sales force competition, input and output pricing determinants and external capital markets could constitute meaningful modeling extensions in relation to corresponding sets of information requirements.

At a more mechanical level, better defined extensions addressed to alternative product distribution systems and modified computer hardware and software configurations associated with the computer-based operating systems have been tentatively examined. In this context, extensions can be viewed as operations research models or subsidiary simulation models imbedded within the primary system model.

An essential aspect of the computer-based modeling and analysis process is the degree of flexibility which can be marshalled to incorporate diverse analytic capabilities within the evolving system model.

A number of potentially significant extensions including models of relevant national and international economic relationships, sales forecasts and new product evaluation models have precedent in the literature with various methodologies and application objectives. Often these analyses require inputs and expertise substantially beyond the scope of the high level analysis process. At this level, the possibility of segmenting modeling and analysis projects with provision for appropriate elements of integration or coordination may prove to be a more effective approach than attempting to extend a single formal system model to encompass such broad and diverse objectives and requirements. The concept of fully modular modeling with each aspect or module of the total model being defined in terms of semi independent objectives and methodologies has been explored in the literature, but meaningful application of this concept to significant systems is currently at the fringe of state of the art capabilities.

OPERATIONAL EXTENSIONS

A number of operational problems and potential extensions have been identified in various contexts above. Among these have been the man-machine interaction implications of heuristic model development, more effective interrogation and reporting functions including graphic displays and a systematic methodology for maintaining modularity in model structure. Beyond these questions, perhaps one of the most interesting and significant current research areas relating to simulation based analysis concerns the development of optimum search techniques or "simoptimization."

Many of the measurement applications and other elements of simulation based analysis discussed above essentially beg the question of how heuristic search procedures can be effectively structured in the context of complex system models incorporating large numbers of interdependent variables. The traditional literature pertaining to optimum search techniques constitutes a potential contribution to this question but some integrating framework is required to effectively bring these isolated techniques to bear upon significant problems.

Perhaps the most promising framework emerging at this time is associated with Markowitz and Luther working from a study initiated by the Office of Naval Research in the mid-1960's[1]. This framework represents a three phase methodology for simoptimization consisting of (1) the "decentralized gradient approach," (2) the "linear response surface approach" and (3) the "quadratic response surface approach." In the order listed, each approach is more expensive to implement, produces more nearly optimum results and converges less rapidly than its predecessor. Limited empirical tests to date suggest very promising results from this framework but further research and elaboration is clearly required.

ORGANIZATIONAL IMPLICATIONS

The high level analysis process suggests a number of organizational and behavioral requirements and inquiries. The organizational structures and participation required support the analysis process, the effectiveness of the operational system model as a communication and training vehicle and the possibility of incorporating behavioral variables in the formal system model were a few of the related topics briefly touched upon above. Undoubtedly some of the considerable work undertaken in the behavioral sciences through simulation based studies could be brought to bear in extending and elaborating the present framework.

An interesting potential extension of the objectives of the high level analysis consists of the redefinition of selected authority and responsibility centers to correspond with significant systems interdependencies identified through simulation based analysis. Where significant suboptimalities arise from conflicting local decision processes, perhaps in the context of resource budgeting in related sequential processing operations, some centralization or centralized control of these local decisions may be appropriate. Similarly, where new or modified decision criteria are required, as in the case of processing and error rates dominating the significance of processing costs, new authority and responsibility might be appropriately lodged with the relevant decision maker.

These possibilities suggest the necessity for redefining the relevant dimensions and relative weighting of multi-factor responsibility centers constituting responsibility accounting systems. In this sense, the operational system model may provide a basis for developing more meaningful coding structures not only across responsibility centers, but profitability, investment and various planning centers as well.

SUMMARY

The preceding sections have identified selected areas for further inquiry. While this outline is far from exhaustive, it is clear that many significant questions involving various disciplines and perspectives remain to be investigated. Resolution of these questions will require interdisciplinary efforts which are only beginning to be developed.

To some degree this openness of the high level analysis methodology is indicative of the relatively recent application of many of the technical capabilities involved and the relatively limited number of organizations presently constituting what has been defined as an advanced management environment. As this set of organizations is enlarged and applied experience with simulation based analysis is accumulated over time, a more definitive closure of the methodology will undoubtedly evolve.

FOOTNOTES

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