SPECIAL REPORT

SEPTEMBER, 1972
THE SOCIETY FOR MANAGEMENT INFORMATION SYSTEMS

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This special report contains two occasional papers, the first by Terrance Hanold (President of the Pillsbury Company), and the second by Dr. James Emery (President of the Society and Professor of Management at the Wharton School of the University of Pennsylvania). Mr. Hanold's paper is an executive's reaction to Professor Dearden's views in the article, "MIS Is A Mirage," appearing in the Harvard Business Review. Members of the Society may find Professor Emery's paper useful for themselves, in clarifying what is meant by MIS, or in educating others about the field of information systems.

The publication of this report is consistent with the Society's philosophy of encouraging interchange of opinions and views about MIS. The Award Paper Series, which will begin publication in 1975, will further such interchange and, hopefully, assist in the formation of an underlying body of knowledge in the Information Systems area.

Gary W. Dickson, Chairman
SMIS Publications Committee
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THE EXECUTIVE VIEW OF MANAGEMENT INFORMATION SYSTEMS

by

Terrance Hanold
President
The Pillsbury Company
Minneapolis, Minnesota

The following is an unedited address given to the Midwest Conference of Financial Executives on June 25, 1972. Mr. Hanold is an Honorary Founding member of SMIS.
THE EXECUTIVE VIEW OF MANAGEMENT INFORMATION SYSTEMS

The subject assigned me has to do with management information systems. Contrary to my habit, I propose to address myself to it forthwith.

Whether there can be a management information system was once a matter of great debate. And there were signs for a time that exhaustion had settled the issue. The debate had been prolonged, but hardly profound, so we were grateful for the respite. But since I accepted your invitation to speak, the charge that MIS is a mirage has once more been raised in the Harvard Business Review.

Truth it seems is always on the scaffold and Error on the throne.

Scholars, too, I suppose are human. At least the claims of charity require this assumption. But where the rest of us rely simply on blunt assertion to support our biases, they with greater guile clothe their prejudices in the guise of reason.

The classical and perhaps the deadliest weapon they employ for the subversion of truth is the scholastic apologetic debate where the academicians pick an absent opponent, often unnamed and always unaware of the contest, sets all the terms of the argument, imposes all of the assumptions employed, and if he is worthy of his Ph.D., demolishes his adversary with considerable ease. This, of course, is the favorite strategy of those who write business review articles. It is a despicable, villainous device.

Let me advise you in confidence that this is exactly what I now propose to do myself.

As the description of the system he proposes to disprove, my anonymous antagonist (John Dearden, Herman Kramen Professor of Business Administration at Harvard University, "MIS Is A Mirage," Harvard Business Review, January-February, 1972, p. 90) quotes the following:

A management information system is an organized method of providing past, present and projection information related to internal operations and external intelligence. It supports the planning, control and operational function of an organization by furnishing uniform information in the proper time-frame to assist the decision making process. (Walter J. Kenney, "MIS Universe," Data Management, September, 1970.)

Whether or not acute analysis might modify it in part, this is a competent and sufficiently extensive description of a management information system.

How does a scholar go about its destruction? His first effort at discreditation is to describe it as "grandiose." Aside from the charge itself, he offers nothing but ridicule to support the description. Then to give it a character it does not claim, he attributes to the definition the universal dimension of a total management information system. Quite clearly, the author of the statement makes no such claim of universal content, and it is certainly not fair to attack the definition on that score. It includes only information capable of systematic collection and of organized processing and presentation in a business environment.

The next means of establishing the proposition that MIS is a phantasmagorical mirage is the attempted demonstration by logic rather than by evidence that the creation of a total management information system is beyond the capability of man.

He declares the fact that certain rival business schools now offer MS and Ph.D. degrees in management information systems. Such persons he says "must clearly be technicians and would have little impact on most of the information supplied to management, particularly at upper levels." Since the author is engaged in the manufacture of Masters of
Science and D.B.A.'s, his authority on this point for exceeds mine, and I must accept his estimate of their fundamental incompetence to create a useful product. So this category of potential inventors of an MIS is by concession disqualified.

In order to disqualify the rest of the world, he imposes upon us his conclusion that the creator of a management information system must be a specialist, that he must attack the information system as a whole, and that the systems approach must be used in making that attack. This, of course, indulges in the contradictory assumptions: (1) that management is incapable of participating effectively in the design of the content and methodology of an information system; and (2) that anyone outside of management would be incompetent to define what management needs. By this system of logic, he attempts to disqualify that part of the world other than doctors of philosophy from competence in this field.

But the only person unequivocally excluded by this mishapen logic is my anonymous antagonist himself. The willful logic of small minds is hardly the proper test of the fact or possibility of an MIS. The best evidence I think follows from experience. With this beginning I should like to describe how an MIS comes into being, where its direction and control are properly lodged, and why it is essential to a modern business organization of scale.

Information

Information is at the core of my subject. Hence a few minutes' reflection on the nature of information is an unavoidable inconvenience.

Information has to do with the communication of knowledge inspired by observation; with the interchange of thoughts and ideas proceeding from experience. As a more intuitive and systematic information in the critical case. It is occasionally an essential exercise of business expertise. Mutations in corporate practice are as necessary as in the realms of nature when environmental adaptation requires it. But it has an infrequent place in the continuing conduct of a business. And it is legitimate for use in the exceptional case. The systematic information has been examined and found not quite adequate.

Business information, then, requires the systematic collection of data and its systematic processing according to a series of intellectually valid methods. The output of the system will communicate knowledge which will dictate or assist the selection of action decisions in fields to which the data and the methods are relevant.

Managerial Information

I have been instructed to consider the nature of managerial information. Is managerial information a subclass of business information? We may at least assume that to be the case for the purpose of inquiry. And it is certainly true that, as there is a hierarchical difference between data and information, so there are hierarchical differences between the several levels of business information and between the information systems which serve them.

Ladies and gentlemen, I am acutely conscious that I have been painfully pedantic for some minutes.

It is to be regretted that I shall continue in the same rut.

Information Systems

The definition of a management information system raises the fiercest disputes vested since the Diet of Worms. As an honorary founder of the society for management information systems, I follow its proceedings with the closest attention. Since the scope of its function obviously depends upon a definition of such systems, it is an area of perennial controversy among some of our members.

After much informal debate and a few unliteral pronouncements by our more authoritative fellows, a formal colloquium on the subject was arranged. For eight hours the subject was collectively threshed. Each participant assailed every definition proposed, including his own, from lid to liboim. [Note received acceptance by vote, consensus, or extraordinary perception.]

So the field is free to each to adapt his own as long as he agrees to impose it on no one else. Perhaps the humanistic approach suggested by Bishop Walston in opening one of our annual sessions is the most appropriate for group therapy. He said, by way of parable, "It is almost impossible to define an information system, but it is easy to recognize one." So I shall describe a managerial information system as I see it.

A management information system defines the data needed to generate the information required to serve a specific business function. It employs a data collection system; a data transmission system; a data storage system; a data retrieval system; an appropriate array of intelligence infusion systems, which are usually described as software or application programs and which employ the principles and methods of the function or discipline served; and an information communication system.

MIS Described

As distinguished from an information system, I conceive a management information system to consist of a cluster of business information systems. If I can find breath to elaborate—

MIS is a symbol rather than a descriptive name, which designates an integrated complex of information systems of such variety and sophistication and interrelationship as experience qualified by rational assessment determines to be essential or useful to the general or executive management of the business enterprise. (This comprises my maximum mental effort of this morning.)

These are ordinarily conceived to be strung upon an electronic network with a myriad of mind-boggling devices. For any particular information system, it may be demonstrated that there is no use for a computer or random access files or remote terminals or any of the other electronic gear that decorates our offices and inflates our equipment accounts. The span and effectiveness of the information system justify its name, not the apparatus which serves it.

But the conduct in concert of a complex of information systems is in practical terms impossible without a computer.

The Accounting Information System

Accounting supplied the first business information system, I suppose. Accounting defined the data needed to generate the information required for its purpose as accounting relating to the assets and liabilities of the firm and to transactions affecting those assets and liabilities. It collected the data needed by the accounting system through the Day Book, gave it order by processing it through the Journal, and meaning and relationship by transferring these entries to the Ledger according to the shifting principles and prejudices of the
Accounting communicated the resulting information through the Balance Sheet, Profit and Loss Statement, and supplementary schedules.

From the accountant's viewpoint, the compilation of time have made a transfer from manual to mechanical to electronic methods tolerable. As far as he concerned, no change in the account information system has occurred in consequence of this shift in tools. Taken by itself an accounting system is an accountant's information system and not a managerial information system. Only as it becomes entwined in a complex of several information systems does it become a part of a whole deserving that eschat.

**Accounting and MIS**

An MIS dealing with numbers of information systems as an Integrated complex can hardly be established or operated or utilized by management unless they are all threaded together on a computer directed network. And if it is to succeed, the threading must somehow be directed by the management, not by accountants or systems or other functionaries. Let me try to illustrate this point by a scatter of examples from one of our businesses — our flour milling enterprise.

Each car of wheat received at one of our flour mills results in an entry which discloses the cart per unit, an official classification, an official grade, a total weight, a protein analysis, a bin location in our elevator where it is stored, a freight transit credit in most cases and several other bits of data. All of these pieces of data are collected in our central data bank.

In the course of processing this data, we derive an inventory of our wheat. Since each shipment loses its identity in the bin in which it is placed, the inventory basis in bi is an average of the type, grade, protein, cost, and so forth of its contents. We derive accounts payable in favor of the seller, transfer credit account and other financing affiliate of the milling accounting process also result. So by processing this data into like or related classes, we begin its transformation into information.

Concurrently, it is hoped, sales of flour are being made. As orders are received, they are scheduled for production. The central production department allocates orders among the mills by means of a program which employs inventory data, data respecting the location of each mill, the character of wheat supply tributary to each mill, the delivery point of the order, the availability of transit milling suitable for application to its further shipment, the specifications of the flour ordered, the capacity and load balance of our mills, and so on. This determination rests on algorithms which have reciprocal as well as consecutive relationships and hence are handled best through computer-administered programs. These programs employ both raw data from the data bank, as well as information derived from the accounting system. So information at one level of use is merely data at the next.

On receipt of its production schedule, the wheat committee at the mill uses another computer program to determine the optimum cost and quality of wheat mixes to be used to produce these orders. It is based on data respecting its wheat inventories and the array of orders directed to be placed on the mill. It also uses subjective data in our data bank respecting many functional characteristics of various types of wheat, their several milling qualities, yield, and so forth. This program, of course, serves also to indicate the specified order in which these shipments will be manufactured.

The wheat procurement department is advised of the planned depletion of stocks by kind, grade, and amount. So having a view both of the kinds and qualities of wheats consumed, of the future orders received or anticipated for milling at that location and the destination points, it makes plans for purchasing wheats in the market of the predicted type, grade, protein, origins, destination, etc. Again, in making this decision, accounting information is used in combination with a great deal of historical crop and sales data.

Through these processes, an immense amount of market data is analyzed to internal and seasonal uses of present and potential customers by product and by delivery point. Employing models of several kinds, the marketing department can determine the most profitable mix of products to sell to whom and at what destinations and by sales periods. In consequence, it is able to assign specific targets by time period, by customer, and by product.

Finally, the general management in flour milling is able to make medium term forecasts, taking into account estimates of wheat supplies by origin, type, cost, estimates of the effect of these elements on prices, margins, volumes, and product mix by market area. By varying the data and assumptions, they derive alternative strategies to fit changes in wheat supplies, transportation costs, competitive action, and other contingencies. Necessary capital investments, distribution network, sales force assignments, and personnel requirements are also indicated.

What we see here briefly and simplistically is the transformation of data to information for use in immediate departmental actions through the injection of the functional intelligence of that department. Each information component is successively woven into other data processed through further functional methods and intellectual disciplines, we ultimately reach a system complex and a volume and variety of informational flows which begin to match the needs of the general or executive management. Only at that point do we begin to identify the label of a managerial information system.

The structure begins with the primitive selection and abbreviated classification of data according to the accounting dictate. Accounting is first concerned with an orderly record of every item moved and transformed from firm assets and of every contract and obligation of the firm which may enhance or diminish those assets.

This is first-level knowledge of critical importance which is not diminished by its position in the managerial scale, but only rationalized or utilized as the other facets of the data. The central issue is, does it apply all of the talents, such as procurement, production, finance, and marketing, that the development of managerial information requires.

Information begins with data, but it is data infused with an organizing and purposeful intelligence. The initial intelligence applied to data that of accounting, but a whole array of disciplines is introduced into the process as it proceeds to managerial intelligence. The basic data of the data during these successive processes is perpetually expanding in both detail and extent.

Thus, information is data infused or refined by intelligence so that it communicates meanings not immediately reflected by the data alone. When information is communicated, it informs either or both of the parties involved. But the nature of the information conveyed will differ according to the function of the person informed and according to the point in the informational hierarchy from which he derives his information.

Where Are We?

We have arrived at the conclusion that accounting produces on immense system almost tailor-made for accountants. We have found that an accounting system is not an MIS because it is not designed to develop the data or to communicate the information required by the multiplying disciplines which must today feed business management. That system is designed to collect only such data as accountants deem relevant to their function and to put that data in such order, to marinate the data in such values and principles, and to subject the data to such procedures as are embraced in their particular functional philosophy.

Quite clearly my argument has gotten off course because these are not conclusively comfortable to those attending this session. If I see, at this moment, to assume a protective posture, there is reason for my stance. In my defense may be permitted to say that in my view Karl Marx somewhat overestimated the case when he described accountants as "jedicals of capitalism." Disappointment is the product of expectation. As I remember it, twenty years ago the accounting profession felt it had the key to dominance in business decisions. It appeared to sprout from the revolution by our outside auditors of the breakdown chart. From the ranges of results it displayed we could readily select the proper sales and costs levels we ought to obtain, garlanded with an attractive ROI. And these results could be neatly battered down and guaranteed by a set of controls derived from the DuPont chart room and administered by the accounting department.

Controls could forestall all mishaps and assure a golden future. And obviously the Controller would be suitably adorned withuition and powers and a seat at the right hand of the Chairman Almighty.

But something unflinching happened on the way to the Board Room. A number of analyses have since been made, and there are several nominees for the blame. And, of course, there is blame enough so that it may be distributed lavishly among them.
Charity forbids that they be singled out. Collectively we may designate them as the inciters of the knowledge revolution.

Technology made huge additions to the stock of data which could be made into business information. Computers performed its transformation at speeds and costs which it economically useful. Computers also gave entry into the office of the "Science of abstraction"—mathematics. In a multitude of applications. This led to the professionalization of the established branches of business and to the invasion of the counting room by a host of new sciences and professions. Both the effect and the cause of this change from skill-centered craftsmen who knew their job to knowledge-centered professionals who knew their world was the transition of the business information base from a transaction record to a data file enormously wider in scope.

So business has advanced to the statistical analysis of the present and the mathematical computation of the future. By the Controller was left to this arithmetical accounting of the past.

Sic Transit Gloria, What Now?

Fifteen years ago the Controller had the only rational information system in the firm. Today every department in the firm is developing a business information system suited to its function and the general and executive management are securing, by acquisition if not by design, a management information system which is the comparable sum of the lot, plus the contribution made by executive management themselves as required by their own functions.

Can the Controller recapture the Information monopoly he once embraced? Can he again become the crumpler of the only game in town? I think not.

Each Information system requires of its governor expertise in the function or discipline it serves. And an Information system forms an organic union with those it serves. As Professor Whisler puts it, "Older technologies are extensions of man's hands and muscles and were his tools and servants, while modern Information technology is an extension of man's brain and is his partner— or even his master." No manager can afford to tolerate an interloper here. He must establish his own direct, continuing, reciprocal, interacting involvement in the system, subject to no man's leave of hindrance and certainly subject to no man's control.

For these reasons, Pillsbury's corporate policy obliges each of its operating firms "to obtain full utilization and value from Pillsbury's Business Information System." To ensure this result, the policy provides that "the General Manager must assume responsibility for the definition of the information and processing requirements of his operation." A "senior professional from the corporate department will be attached to the (firm) to serve as the General Manager to fit in helping him to define his subsystem's requirements."

This same concept is carried to the corporate level. Our policy states that "Certain affairs of the Pillsbury Company are inseparable from its Executive Office. Among them is the Pillsbury Business Information System. Without immediate control of the design and operation of this system in its entirety, the Executive Office cannot effectively function. It is for this reason that PIBM reports directly to the Executive Office."

What Next?

What becomes of "managerial accounting for decision making" in such an environment? How am I to deal with a letter from a young and ambitious member of the Controller's group who expresses his point of view by this textbook quotation: "...it is felt that an accountant's role should not be confined to merely dealing with historical systems, data and controls. Along with looking at the past and present, he must also look to the future of the company which he serves. Nor should he be narrowly viewed as a corporate policeman, but more as an objective viewer of the corporate reality (performing an evaluative-management function). While he may not be the supplier of answers, he can at least help to raise relevant questions and identify problem areas."

These phrases have a singing quality which appeals without persuading. It is the accountant's instinct to coach the manager respecting the decision he makes, and at the end of the year, it is his function to sit in judgment on the results of those decisions. You and I understand the game, but the gods who are answerable to the world for the published results do not.

They think it indecorous for a man to urge a decision while uncommitted to its consequences. And they think it indecent, to put the matter in its politest terms, for him later to publish, underline, and critique these consequences when they prove unfavorable, while hiding under the flag of neutrality that his accounting title gives him.

The burden of management is to influence the future favorably, and even predictably. A leading partner of one of the principal public auditing firms remarks that in the torrent of change which tosses enterprises today, "Success in committing resources to profitable opportunities is being measured less and less adequately by focusing on profits achieved... The concepts proposed in this discussion are based on the firm conviction that generally accepted accounting principles, as they are now constituted, and the management accounting practices that result from them, are inadequate—that they cannot respond to the forces of society which are today, calling for meaningful information."

As a remedy he proposes a scheme of "entrepreneurial accounting"—a scheme for reflecting the future profitability of a firm—which would alter accounting concepts long in fashion, but would do little to enlarge the basis of judgment for the area of certainty for a manager required to deal with "problems" which have been exponentially expanded."

We are dealing, of course, with the ancient urge toward agrandizement of function which is neither foreign nor peculiar to accountants. And the supporting rationale is seductive. Accounting has supplied the institutional processes of management in the past—why not enlarge its domain so that it embraces the whole information structure on which managers depend?

A computer environment does add a favorable time advantage to a firms' information system which suits it to use in the arena as well as in the post-mortem parlor. This new dimension offers accountants the temptation to float widely over the whole Information range. But they enlarge their span of activity at the peril of loss of stature and effectiveness which depends on their responsible obedience to the limits of their professional domain.

Accountants have the capacity to convert accounting data into information because their professional training qualified them to influence that data with accounting Intelligence. Outside their field they become mere data gatherers, for their training gives them no special competence to convert data into the marketing, production, procurement, or other information systems which ultimately fuse into an MIS. If they attempt an indiscriminate power of dictation in areas outside their own field, they lose their professional identity and become simply computer systems technicians.

Worse, they become a well-meaning but formidable obstruction to the creation of the end they say they desire—a true MIS, for they deter the entry of the variety of talents, disciplines, and intelligence necessary to that end. The fact is that no single function or discipline can furnish a sufficient information base for management. That is why we have kept our Information systems free of the grasp of any one function. Thus, we have enabled our managers to draw the informational output of every function freely into its channel. Each functional Information system is the responsibility of the functional manager in matters of design, structure, and purpose. The MIS is the responsibility of the general and executive management.

Also at the heart of the matter is the distinctive character of the accounting function. Here we come to the point of division. MIS is essentially an operations system completely separate and distinct from the management function. Accounting, control, and audit are essentially an evaluative system—a system for ensuring management and hence necessarily outside of the management function.

Accounting's prime concern was once with the form of the entry and how it should be with the clarity of the disclosure. Its function was once private and procedural. It is now professional, charged with public trust. Recognition of this obligation will be a business landmark in the 1970's. The primary of their fiduciary duty will preclude conflicting practices, such as are implied by "managerial accounting," or entangling alliances with management which their dominance over MIS would create.

The accounting fraternity is under a fiduciary obligation to the Board of Directors, to the owners, and to the public in general. High performance evaluations of the firm and its management. The success of an accounting Information system is measured by the support it furnishes to the discharge of this mission. Happily, the better the accounting
Information system serves this end, the more useful are its inputs to the MIS because they more faithfully and fully reflect professional accounting intelligence.

Not only must these evaluative judgments be made free of bias, they must be free of the suspicion of bias which comes from a compromising involvement in the operative management function. The fiduciary obligation must rest on the Information staff as well as on the outside auditors. For I cannot conceive looking to the future, how an outside auditor can certify financial statements prepared by a staff whose interests are conflicting and whose loyalties are divided.

It has been argued that thus limited the accountant's role is simply demeaning. In my opinion, the inputs we get from men who maintain a position of professional integrity are of the ultimate value in the heat of pressured decision. In my opinion the counsel of those who rightly maintain the posture of counselor will be of highest worth to those who have the burden of management in this decade. Those who counsel on the basis of professional principles profoundly understood and respected have a value beyond measure. And their value is the greater because they counsel rather than control, because they reason rather than rule.

A great profession is one whose practitioners think greatly of their calling. Perhaps the privilege of a proud self-regard, justly entertained, is the greatest reward that any future employment can offer.

The Financial Officer.

One of my associates has pointed out an uncomfortable omission in my argument which requires a further point be made. In an accountant's working day role, accounting may be "merely a subset of the substance of his function." It does not recognize "the double identity of a controller, as chief accountant and as financial officer." And my friend puts into place the proper recognition of the critical leadership and contributions which our divisional controllers have made to the development of our MIS, not only in the areas dealing with the hard facts of the past, but in the systems designed to "record, process, and evaluate the uncertain future of an uncertain world."

He also establishes the interesting proposition that certain of our controllers took the initiative in developing tools for decision making in the management world of uncertainty, and that their example finally led to the "encapsulation" of these "managerial" functions from the traditional controller's control. So we attain again unto the revealed truth that decisions pertaining to the uncertain present are the prerogatives of management, not the controller.

But there are some decisional areas often managed by accountants which are beyond the areas of transaction record, control mechanisms, and evaluative measurements and judgments of management. These are the functions of the financial officer.

To adopt my associate's conclusions, "A clear distinction is needed between the controller as an accountant and the controller as a financial officer. The function of finance is distinctly a managerial function dealing with uncertainty, as such as the other functions (marketing, production, etc.). The finance officer has to deal with the timing of finance decisions, the choice of sources of financing, the control of liquidity, the estimation of future shortages or surpluses, and predicting future interest rates. His information system is distinguishable and separate from an accounting system. However, there is a tendency for financial officers and chief accountants to be identical and drawn from the accounting profession."

As in all cases where an absolute line of division is wished for, there is a band of overlap. At the operational levels in the firm these may be both necessary and extensive. But at the senior policy levels it is undesirable and in my judgment will not long be tolerable.

Theoretically, as my friend supposes, the fiduciary character of the Controller has always existed. But the focus of responsibility continually shifts with the scale and mission of our institutions and with the ideals and objectives of our society. So the fiduciary nature of the Controller's function has advanced from an occupational aspect to the dominant character of his function. (Walter F. Frese and Robert K. Mautz, "Financial Reporting By Whose?" Harvard Business Review, March-April 1972.)

Hence, while the financial office is derived from the accounting function, it has attained a status and character distinct from that of the Controller. Prediction is the dominant contribution of the financial officer, who is preoccupied with the acquisition and allocation of resources by the firm; while the designation and measurement is the prime concern of the Controller who accounts for the inventory and evaluates the benefits of the corporate resources.

Finance by its nature adheres to management. The Controller by his function must be allied to ownership and its representatives, the Board of Directors.

The Imperative Necessity for MIS

I must now return for a closing session with my anonymous adversary. He contends that a series of business information systems, each oriented to a particular function or operation, must result in an MIS which is uncoordinated, and therefore inefficient and unsatisfactory. Because of the vast differences which necessarily exist between these several systems created for accounting and control, for production and distribution, for marketing, etc., he contends that expertise in one area is of little value in another. It follows he thinks that since one central mechanism may dominate the desires of every system, there can be no single homogeneous MIS embracing them all.

If we followed the same logic we must also conclude that there cannot be a firm of size or complexity because no one man has the talent to master every function and operation necessary to the accomplishment of its mission. Consequently, according to this test no one is qualified to manage in total. Perhaps we have inadvertently stumbled upon the flaw in the system. But the fact is that we do have the Executive Office, and it is required to oversee the whole of the firm. And it must have an MIS to do the job.

The key to MIS is an integrated data base, not a universal genius expert and omniscient in every thing. As we have noted, each of the functional systems utilizes data and output from other systems as well as inputs from sources peculiar to its function. From these materials it generates information suited to the performance of its particular function. And this information also feeds back into the data base where it is available as data for all of the other business systems.

It follows that if our functional information systems cover the operations of the firm with reasonable sufficiency, there is information in the data base adequate to support an executive management information system. Some further data will be needed, of course, because executive management considers a different opportunity horizon and a different time span than does operating management. But with this minor qualification the material is at hand to do the job.

And the job is no more complex, indeed it is less so, than the problem of creating the several operating systems. The critical problem to the construction of an MIS is the integrated data base itself. This requires first a unified communication system through which the system data must flow; it requires rapidly expanding data file facilities; and it demands a data coding and addressing scheme which makes all the data in the bank reasonably available (hopefully randomly and instantly available) to every system in the firm.

The real obstacle to MIS in vast firms is the structure of the data files themselves and the means in hand for accessing them. Without adequate methods and structures here the problem of system interfaces—which means people interfaces—becomes the condition precedent to performance. And a guarantee of unsatisfactory performance. My anonymous antagonist says that this is a matter to be solved by education, but as you will recall he disapproved B school products as a solution much earlier in the game. So he is bucking the problem to some other branch of learning when he takes this tack. And indeed he classes his article in a state of hopelessness:

Management must always operate with insufficient information. In many areas the truth of these statements is becoming more salient because while the role of management is becoming more complex, the new information technology is not helping significantly. The problems of control in decentralized companies are much more difficult than they were ten years ago, increases in size, complexity, and geographical dispersion have made control much more difficult. Yet the new information technology has been of little help in this area, simply because the problems of control in decentralized companies do not lend themselves to computerized or
mathematical solutions... part of our information crisis results from the nature of the present business environment. We shall simply have to live with it.

This is a perfect demonstration of the absolute necessity of MIS, and a complete admission of the impossibility of reaching it through his approach. He has discredited people interfaces as a means of establishing data flows between related information systems. He has failed to see either the necessity or feasibility of avoiding this impediment by an integrated data base.

For we shall not reach the MIS we need for the management of the enterprises we have created through the scholastic logic bequeathed us by a medieval heritage. We shall reach it by the perceptive application of the information technology which daily experience teaches, if we are disposed to learn.
AN OVERVIEW OF MANAGEMENT INFORMATION SYSTEMS

by

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AN OVERVIEW OF MANAGEMENT INFORMATION SYSTEMS

1. Organizations.

1.1 The role of organizations. Our lives are continually influenced by organizations. We work in them, buy from them, are educated and governed by them. Whenever we set out to accomplish something that requires the cooperation of more than a few persons, we establish some sort of organization to parcel out tasks directed toward the achievement of our goals.

Our concern in discussing management information systems is with the larger organization that requires a formal means for planning and coordinating its activities. Small organizations, composed of perhaps a dozen or fewer employees, may not need a formal system; coordination can often be handled through informal personal contact and "back of the envelope" record keeping. As the organization grows in size and diversity, however, informal procedures no longer suffice. Poor coordination and execution begin to exact increasing penalties. Eventually an organization finds that it must develop a formalized information system if it is to cope with its added complexity. The transition from informal to formal system is a critical juncture in the life of an organization—one that often proves to be both difficult and hazardous.

Organizations come in all sizes and types. The most common type is the business firm. These organizations span a bewildering variety of activities—such as manufacturing, mining, construction, utilities, retailing, banking, insurance, transportation, communications, and entertainment. Some of the larger firms may find themselves in a wide range of industries and worldwide markets. It requires an enormously complex information system to coordinate the diverse activities of such an organization.

Not all organizations are profit-seeking firms, of course. Government agencies, educational institutions, hospitals, professional societies, charitable institutions—all are organized in much the same way as the business firm. All except the smallest require some form of information system to carry on their activities in an efficient and coordinated way.

The goals of organizations naturally vary widely. In principle, the business firm aims at long-run profit maximization, while a government agency or philanthropic institution presumably seeks to provide a needed service at an acceptable cost. Despite this diversity of goals, the problems faced in designing an information system are much the same, regardless of the type of organization for which the system is developed. Specific details of a system are unique to an organization, but general techniques and approaches to implementation apply broadly across all organizations and functions.

1.2 Complexity of managing an organization. The myriad activities of an organization are directed toward a set of goals. Coordinating all of these activities is an enormously difficult problem in even a moderately sized organization. It can never be done perfectly; one must instead settle for a reasonable compromise between the costs of coordination and the penalties associated with a lack of it.

Size alone contributes to the complexity of coordination. A large international corporation may have over 100,000 employees working in plants and offices throughout the world. The U.S. Defense Department, which is only one part of the Federal government, employs over two million people and manages a vast array of facilities and activities scattered over the face of the globe.

More important than mere size is the extent of the interrelations among the organization's activities. Consider, for example, a large manufacturing firm. All of its major functions—e.g., marketing, engineering, manufacturing, purchasing, personnel, and accounting—are linked together in order to carry out the activities of the company. What happens in one function may affect all other functions. Coordinating them so that they fit to—
gather and contribute to the achievement of the firm's goals is one of the most complex tasks facing management.

It is primarily through the formal information system that a large organization plans and coordinates its activities. The formal system includes all explicitly defined information processing within the organization. The informal system—casual personal contacts and observations, the "grapevine," and so forth—plays an exceedingly useful role, but it is normally far too limited, inconsistent, and spotty to rely on as the major vehicle of planning and coordination. The aim should always be, therefore, to formalize required information processing.

Planning and coordination call for the exchange of information so that each organizational subunit knows what is expected of it and how it must mesh with other subunits. Figure 1 shows some of the typical information used to coordinate operations in a manufacturing firm.

Information Inputs
- Sales orders and forecasts
- Engineering data
- Cost data
- Operating budgets
- Long-range capital budget

Information Outputs
- Shipments
- Cost and schedule performance
- Purchase requisitions
- Personnel requirements
- Production schedules

Physical Inputs
- Raw materials
- Labor
- Capital equipment

Physical Outputs
- Manufacturing
- Finished products

Figure 1. Information required for coordination.

In order to plan its activities, each organizational subunit must obtain information from higher level management and from other subunits. The manufacturing department, for example, requires sales and engineering data, operating budgets, and long-range plans. It, in turn, provides to other subunits information about its performance, its resource requirements, intended schedules, and the like.

The distinction between operating and status information is the same as the difference between an accounting income statement and a balance sheet. Forrester (1961, pp. 68-69) uses the term "state variable" and "level variable" to express this same distinction.

Information flowing through the system takes many forms. Among them are the following:

- Operating documents used in the routine activities of the organization. Examples include paychecks, invoices, purchase requisitions, and shipping papers.
- Directive information used to guide the behavior of lower level units. Such information is expressed in the form of budgets, schedules, and so forth.
- Information about operating performance and current status. Performance data include sales, shipments, profits, and cash receipts occurring over the most recent accounting period (a month, say); status data include backorders, inventory levels, net worth, and cash balance.
- Data used in planning future activities, such as sales forecasts, standard material or labor costs, and the plans of other organizational units.
- Environmental data, which give information about matters external to the organization. Examples include economic indices, demographic data (from the U.S. Census, say), reports of competitors' activities, and important social or technological developments.

Information of this sort ties together organizational units that would otherwise be merely a mish-mash of fragmented activities. The behavior of the organization depends largely on the characteristics of this information—its content, age, accuracy, reliability, and so forth. Like the nervous system of an animal, the information system coordinates the parts of the organization to direct all activities toward common goals.

1.3 Complexity of a comprehensive information system. A comprehensive computer-based information system for a large organization is probably one of the most complex artifacts constructed by man. There are a number of factors that account for the complexity of a large system:

- It typically deals with very large quantities of input data. The collection of the data is expensive and error prone and must therefore be carefully designed to increase efficiency and keep the number of errors to a tolerable limit (which is in some critical cases may be extremely low).
- Large volumes of data must be maintained more or less permanently in data files. Often separate records within the files are related to one another in complex ways (such as two separate insurance policy records relating to the same policyholder).
- A large variety of programs must be written to accommodate all of the organization's data processing requirements.
- Processing procedures and decision making aids are intimately linked with each organization's business practices and the peculiarities of individual managers. This reduces the extent to which standardized procedures can be transferred from one organization to another.

2. Ongoing operations must continue, thus requiring extremely careful conversion from an existing system to the new one (often over the course of many years).

- Many parts of the system must mesh together into a working whole.
- The magnitude and complexity of the task imposes a need for many persons whose efforts must be closely coordinated over a considerable time period.

A comprehensive system takes many years to implement (if indeed it ever gets "completed"). It is impossible to anticipate changes in the needs of users and advances in technology that take place over this length of time. The only thing that is certain is change.

2.1 The effect of the information system on the firm's performance. The goal of Able is, in principle, long-run profit maximization. In practice this fairly nebulous goal may be translated into such operational goals as profit per share of common stock; return on sales, assets, and net worth; rate of growth; and variance in expense ratios. Figure 2 shows the performance of Able during a representative period.

Designers of an information system for Able should be concerned with the major factors that contribute to the firm's success in achieving its goals. Among the more important factors are the following:

- Merchandising strategy (i.e., product selection and promotion, pricing, the form of advertising and product display, etc.).
The design of the information system has an impact on each of these factors. For some the impact is direct and major, while for others it may be relatively slight (depending, obviously, on the features included within the formal system). Let us consider the ways in which the information system can contribute to the firm’s goals.

2.2 Reduced administrative expenses. Reduction in administrative expenses is clearly one of the areas in which the information system can make a direct contribution. A great many routine clerical and data processing operations must be performed in running a large supermarket chain. These include:
- The ordering of merchandise at each store to replace the items sold.
- Processing the order to prepare shipping schedules for the warehouse.
- Ordering merchandise from suppliers to replace warehouse stock.
- Accounting for store shipments in order to measure performance at each store.
- Accounting for receipts from suppliers and the preparation of checks in payment.
- Preparation of payroll checks and accounting for labor costs.
- Preparation of external reports (e.g., tax reports, financial reports, etc.).

For many businesses, “paperwork” as it is sometimes viewed, the processing of information is an integral part of the business. It is an important item of expense, and so a reduction in its cost through greater efficiency can have a very significant leverage effect on profit.

2.3 The logistics subsystem. Reducing the cost of data processing is not the only way in which the design of the information system can contribute to the firm’s goals. Indeed, some of the most important contributions may even increase data processing costs. The justification for any such increase should come from benefits that more than offset the added costs. In the supermarket industry the logistics function offers great potential for improving the firm’s performance. This function deals with the flow of material from the supplier to the warehouse and then to the individual store. Figure 3 shows these flows.

The effectiveness of the logistics function has a direct effect on inventory levels, warehousing costs, and transportation costs. It also has a major effect on supplier relations, store operations, and customer relations. In fact, there is scarcely any activity within the firm that is not affected in some way by the logistics function. Clearly, then, the design of the information system serving the logistics function is critical to Able’s success. The quantitative nature of the function permits a relatively high degree of formalization and the application of advanced techniques of planning and control.

Let us examine the information processing associated with logistics operations. We can begin by considering the processing of orders from the individual stores. Each store manager is responsible for submitting a daily order to replenish merchandise whose inventory levels have fallen below the reorder point. On a typical day perhaps 1,000 different items will be reordered, out of a total stock of about 15,000 different products. The order is prepared by entering the quantity requested on a standardized form. This form is then delivered to the central warehouse by the truck driver delivering merchandise ordered earlier.

The next day all store orders are manually key-punched. This operation simply converts the hand-written orders into machine-readable form suitable for computer processing. All orders in punched card form are accumulated until the end of the day. At this time they are processed together as a single batch.

The processing generates three principal outputs:
- The shipping schedule, which defines for warehouse personnel the shipments to be made to each store.
- Store billing data, which give the value of merchandise shipped to each store (used for financial control and to measure the profitability of the store).
Physical movement of material — Information

Management

Information System

Suppliers — Central Warehouse — Individual Stores

Information Flows:
1. Store orders.
2. Shipping schedule.
3. Shipment to stores.
5. Orders to suppliers.
6. Shipment of merchandise from suppliers.
7. Receiving reports (to report receipt of merchandise from suppliers).
8. Invoices from suppliers.
9. Payments to suppliers.
10. Accounting reports to stores.
11. Reports to management.

Figure 3. Logistics system within Able Markets.

The logistics function deals with the ordering, warehousing, and distribution of merchandise within the firm.

- Stack requisitions, which initiate the reordering of merchandise from suppliers.

The shipping schedule is sent to the warehouse by 7:00 p.m. of each day. The night crew selects the scheduled merchandise from warehouse storage areas and assembles it by store. Truck trailers are loaded and ready for shipment early the next day. Figure 4 shows the events associated with the store ordering cycle.

A simple description of the flow of store orders does not tell the whole story. The information processing that takes place can have a major impact on


day

Day 1
Day 2
Day 3

0800 1600 0800 1600 0800 1600

First
day’s
order

1 2

Second
day’s
order

3 4 5 6

Third
day’s
order

1 2

Activities:
1. Order preparation at store.
2. Delivery of order form to central warehouse.
4. Batch processing of store orders.
5. Warehouse picking and loading of truck trailers.
6. Delivery of merchandise to store.

Figure 4. Processing cycle for store orders on three successive days.

It takes a little over two days from the determination of a store’s requirements until the merchandise is available. Delivery is made daily for most stores, so up to three orders may be in various stages of the cycle at any point in time.

the effectiveness of logistics operations. There are a vast number of ways in which the information system can enhance effectiveness. It can, for example:

- Reduce the ordering cycle—from two days to one day, say. This would permit the store to replace out-of-stock merchandise more quickly and thus provide better service or allow lower stock levels (or some combination of both). The shorter cycle could be achieved by electrical transmission of the order from the store to the warehouse (rather than by truck delivery). Once an order is received at the warehouse, it could be processed quickly as part of a small batch (rather than a single daily batch).
- Enter orders from stores in machine-readable form, thus eliminating the cost, delays, and errors of manual keypunching at the warehouse.
- Increase the efficiency of order picking. The items included on the shipping schedule, for example, can be printed in a sequence corresponding to their physical warehouse location. This would then permit a stock picker to make a single trip through the warehouse to select the items on a given or-
order (rather than back tracking to find items if they were listed in random sequence).

- More effective control of inventory. The order processing system determines when the warehouse stock of an item falls below its reorder point. When it does, a predetermined order quantity is ordered from the supplier. The inventory decisions that determine the value of the order point and order quantity for each item govern the average level of inventory, the likelihood of having a stockout (i.e., insufficient stock to meet store demand), and the number of times the item is reordered from the supplier. A decision model can be developed to compute inventory decisions that will minimize the sum of variable inventory costs—that is, the cost of carrying inventory, incurring stockouts, and reordering stock from suppliers. See Figure 5.

2.4 The role of the information system in other activities. Other management functions can also be aided by similar improvement in the information system. Let us go back to the important determinants of Able's performance to give examples of how the information system might contribute to success.

- Merchandising strategy: The information system can provide analyses of the relative profitability of various products, the effects of alternative advertising and pricing strategies, and national versus private brands.

- Store location: Analysis of demographic data to determine the factors that contribute to a store's profitability (such as average disposable income and population density), studies of automobile traffic patterns, and evaluation of local competition.

- Store construction and modernization: Analysis of alternative store designs (in terms of floor space, shelf space, freezer space, size of parking lot, maintenance costs, etc.), scheduling of construction, and financial analysis of investments in new or modernized stores.

- Personnel policies: Evaluation of management performance and analysis of alternative wage and benefit packages.

- Store operating expenses: Budgetary control of expenses and analysis of expense items to determine their effect on profitability (e.g., checkout counters per million dollars in sales, maintenance policies, and shelf stocking and material handling policies).

- Corporate administrative expenses: Budgetary control and the analysis of major items of expense.

- Financial policies: Cash flow analysis, investment analysis, and financial reporting.

- Supplier relations: Brand profitability studies, analysis of supplier delivery performance, analysis of special "deals" offered by suppliers (e.g., promotional programs, such as "$5 off" packages, discount coupons, etc.).

- Customer relations: Consumer surveys and analysis of customer complaints.

The degree to which the formal information system plays a part in Able's activities is an extremely important design issue. The system may concentrate on routine data processing in the hope of reducing costs; in this case the impact on most activities will be minimal and its contributions to the firm's success will be quite limited. On the other hand, the system may pervade virtually all corporate activities and have a substantial impact on performance.

Information systems are increasingly expanding their role in the organization. The pervasive system provides by far the greater potential payoff, but it does so at a considerable increase in system complexity. The designers should aim for a system that achieves a proper balance between the benefits expected from the system and the costs and risks inherent in developing it.

3. The Effects of Technology on the Information System.

Any organization of even modest size has a formal information system. Systems can vary tremendously in their level of technical sophistication. The objective in designing any system is to achieve efficiency in information processing and to generate information whose value justifies its cost. With today's technology this almost always calls for some use of the computer.

3.1 The computer and related technology. The computer's rate of technological advance has been nothing short of fantastic. Compared to a manually operated desk calculator, modern computers offer an increase in speed by a factor of about 100 million—nearly a doubling in speed each year over the past three decades. The human mind can scarcely grasp the meaning of such a vast increase in speed. Some appreciation can be gained, however, by comparing the advance in computers with that of another well-known form of technology, transportation.

The private automobile provides perhaps a tenfold increase in speed over the horse and buggy; nevertheless, this increase in private transportation has been enough to bring about profound changes in our society and economy (not all of them for the good, unfortunately). The speed of a subsonic jet aircraft is about ten times that of the passenger train, or increase enough to add greatly to personal mobility and other in the life of the jet set. The supersonic jet doubles the speed of commercial aircraft; nevertheless, it still only travels 400 times faster than a man walking.

In other fields of technology, an order of magnitude advancement (i.e., an increase by a factor of ten) has very often rung in a new era. And yet in the field of computers we see a change of eight orders of magnitude compressed into but a single generation. Not surprisingly, we have not learned to cope with our new-found superabundance of computation.
The cost of computation, rather than mere speed, is usually of greatest concern to designers of an information system. Accompanying the explosive increase in raw speed has been a steep reduction in the cost of computation. A large computer performs at a cost of less than ten cents per million elementary operations (such as adding two ten-digit numbers). Since 1945 costs have come down by a factor of over 10,000. If the price of an automobile fell by the same factor, it would sell for about 20 cents. The huge reduction in the cost of computation makes it feasible to employ it lavishly within the information system.

The power of the modern computer is widely available. Time-sharing systems permit widely dispersed users to share a single computer. Each user has a terminal—typically a teletypewriter or a similar low-cost keyboard device—through which he enters data and receives output. The terminals are linked to the central computer over the regular telephone network. Most users of the system only dial a local number in order to connect with the computer.

While the large computers have been getting faster, small minicomputers have been getting cheaper. A stripped-down minicomputer, with internal speeds comparable to the fastest (and most expensive) devices a decade earlier, now sells for a few thousand dollars. For some (specialized) purposes a small dedicated machine offers the most economical means of gaining access to computer capacity.

Before this capacity can be brought to bear on a problem, the computational task must be defined very explicitly. This is done through a suitable set of instructions, called a program. The computer is a perfectly general tool, in the sense that it can accept a program to perform any well-defined computation. For instance, by simply changing a program, the same computer can be instructed to calculate paychecks, keep track of inventory balances, or determine cash flow over the next year.

The computer and its related equipment constitute the hardware of the system; programs constitute its software. These terms have an obvious derivation: the hardware is concrete and "hard," while software exists only in the form of programs stored within the main memory of the computer or recorded on some auxiliary medium such as magnetic tape. Figure 6 portrays the distinction between hardware and software.

Programming typically imposes the most severe limitation on use of the computers. This will no doubt continue to be the case, but considerable progress has been made in relieving the problem. Various higher level languages exist that permit a user to define his problem with relative ease. Indeed, numerous application packages have been developed to provide standard programs for handling common applications; a given user must only adopt the package to his own needs.

While the computer has undergone an unprecedented rate of advance, steady (but less dramatic) progress has been made in such peripheral functions as data collection, transmission, storage, and display. Improvements have resulted in lower cost, greater speed, reliability, and accuracy; and a wider variety of capabilities. These have greatly expanded the range and usefulness of computer-based systems.

Thus, technical developments over the past quarter century have made the computer available for virtually any information system worthy of the name. The power, low cost, wide availability and relative ease of use have made computers an indispensable part of any system that purports to strike a reasonable balance between the value and cost of information processing. This is not to say that all information processing should be performed by the computer—far from it!—but it makes no sense to design an information system without carefully considering the applications for which the computer is well suited.

3.2 Technology of decision making. An organization governs itself through decision-making processes. Hundreds of thousands of decisions may be called for in the course of a day. Each decision process can be viewed as a transformation of information inputs into decision outputs, as shown in Figure 7.

The designer of an information system should concern himself with the three aspects of a decision process:

- The information inputs, expressed in such terms as current, format, timeliness, accuracy, and sources.
- The decision process itself—that is, the way

Figure 6. Computer hardware and software.

Computer hardware exists physically in the form of electronic circuits, storage devices, terminals, and the like. Control of the hardware is exercised through computer software—i.e., the collection of instructions that define the tasks that the hardware is to execute. The operating system is a special kind of software; it handles the allocation of computer hardware resources (processing time, storage, etc.), the sequencing of jobs, and various record-keeping tasks. The operating system is an integral part of the overall computer system, since all other programs obtain access to hardware resources only through the operating system. Some of these other programs perform a generalized system function, such as sorting, standard mathematical operations (e.g., inverting a matrix or calculating statistical regression coefficients), or translation of a higher level programming language (which the hardware itself does not "understand") into machine language (which it does understand and can execute). Still other programs deal with tasks specific to a given application, such as payroll, inventory control, or financial analysis.

Figure 7. Inputs and outputs of an inventory decision process.

A given decision process transforms information inputs into decision outputs. The transformation may be highly formalized (e.g., a computer program), or it may be informal and performed by a human decision maker (with perhaps some aid from the formal system). In this example of an inventory decision process, the inputs include a forecast of an item's usage, the cost of reordering the item, and a constraint on the level of service that should be maintained (95 percent stock availability, say). The outputs of the process define when a replenishment is required and the quantity that should be ordered.
In which inputs are transformed into outputs.

- The decision outputs— their content, format, and the way in which decisions are translated into action.

The preparation of inputs and disposition of outputs often permit considerable formalization. Computers and related technology can thus play a major role. The case is not so clear with the decision process itself. Formalization of a decision process requires the development of some sort of decision model.

A model represents the significant characteristics of a decision process. The transformation of inputs into outputs is expressed explicitly as a series of equations or a computer program. For each combination of inputs the model provides a corresponding combination of outputs.

The nature of the outputs depends on the degree of formalization achieved. The extreme case of formalization exists when the outputs represent optimal decisions—that is, the actions that will lead to the best possible outcome for the given set of inputs. Optimal inventory decisions, for example, minimize inventory costs and optimal scheduling decisions may maximize the profitability of the products produced with available capacity.

Complete formalization of this sort is almost exclusively confined to relatively few, routine decisions; it becomes increasingly difficult to achieve as one begins to tackle the more important long-range decisions. Even so, some significant formalization may be possible. For example, a model may predict the expected consequences of a given alternative action. On the basis of the output predictions, the decision maker may choose to revise his input decision, as shown in Figure 8.

Morton (1971) describes such a man-machine model used to schedule the production of washers and dryers for a major appliance manufacturer. The complexity of this problem precludes a complete formalization, but it is nevertheless possible to formalize part of the process. The model developed provides the human decision maker with significant aid by digesting large quantities of data, analyzing trends, and predicting the consequences of proposed alternative schedules.

Even though formalization may not be feasible in a number of important cases. For example, nonroutine decisions with few quantifiable variables may simply not be susceptible to a significant degree of formalization. Under these circumstances the formal system may do little more than provide a few spotty inputs to the human decision maker. The remaining (informed) inputs, the decision process itself, and the disposition of outputs may all fall outside of the formal information system.

The boundary between the formal information system and the human decision maker shifts with changes in technology. Advances in information processing technology affect the boundary by lowering the cost of obtaining data and performing the computer operations associated with a decision model. Some decision procedures require a great deal of data and seek up a prodigious quantity of computation; they may become economically feasible only after the costs of collecting and manipulating data have dropped sharply.

Advances in the management sciences also strongly influence the acceptable degree of formalization. Increased formalization becomes feasible as the range of models is extended and our experience in applying them grows. In some cases this might lead to complete formalization; more likely, the information system may be extended to provide additional aids to a human decision maker.

Thus, we see that the design of an information system is inevitably influenced by the state of information technology—the technology of computers, communications, and decision making. Although technical competence by no means guarantees success in developing advanced information systems, lack of such competence almost surely leads to disappointing results.

4. Processing Functions Performed within an Information System.

Information systems vary greatly in their environment, complexity, response time characteristics, and so forth. Nevertheless, certain processing functions must be performed as part of any system. These include:

- Data collection.
- Storage.

4.1 Data Collection. The data collection function serves as the eyes and ears of the information system. It is the means by which the system is kept in touch with the real world. When something of significance occurs, information describing the event must be collected and entered into the system. All of the information available within the system owes its existence to this sensory function.

Many decision processes permit only partial formalization. Rather than providing optimal decisions, a model may only aid the human decision maker by predicting the consequences of a proposed alternative. Through a trial-and-error process the decision maker can then search for improved plans. He can stop the process when he judges that any potential improvement does not justify the cost of further search.

- Retrieval.
- Computation.
- Display.
- Transmission.

Suppose a customer of a manufacturing firm wishes to place an order for an item. This event, or transaction, must be described in such terms as the customer's name and other identifying information, his address, the salesman receiving the order, the identification of the item he is ordering, the quantity ordered, and the financial terms of the salesman (i.e., discounts and credit terms). It may require more than 100 characters of information—letters, numbers, and special symbols such as $— to describe the transaction in enough detail to perform the associated processing. Normally the transaction is collected in handwritten form by a salesman.
or order clerk. This constitutes a source document for further processing.

In a computer-based system much of the processing takes place inside a computer. The system must therefore include some means for converting handwritten source documents into machine-readable form. This is conventionally done by a key-punch operator who manually types the information to be collected, as shown in Figure 9.3

Sales orders constitute only one source of data, of course. Information must also be collected about significant internal operations within the organization, such as the completion of a manufacturing job, the receipt of material from a supplier, or the hiring of a new employee. In addition, various forms of environmental information may be collected that describes conditions or events external to the organization.

The volume of data collected can reach staggering proportions. Many thousands of events of potential significance can occur each day. Any one of them may require a few dozen characters to describe it. The cost of collecting such massive quantities of data is often one of the largest single components of operating an information system. Furthermore, the accuracy and timeliness of data entering the system have a major impact on the system’s effectiveness. Clearly, then, the choice of data to be captured and the means of collecting them are among the most important design characteristics of a system.

The designer has available to him a large variety of data collection devices. They differ as to their means of sensing and recording information, degree of automation, speed, form of the output, portability, special features, cost, accuracy, and the like. A typical system may use several different types of device to meet a variety of requirements and sources of information. Figure 10 shows a few typical techniques of data collection.

4.2 Storage. If the data collection function is the sensory organ of the information system, the storage function is its memory. The quantity of stored data may grow to billions of characters in a large system. Typical types of stored information are the following:

- Status information, describing employee characteristics, current inventory levels, capital equipment, and similar "megaphones" of the organization (in whatever detail required).
- Operating information, giving current rates of sales, production, and expenses.
- Existing plans—operating budgets, production schedules, sales forecasts, cash flow projections, financial plans, and the like.
- Planning data, such as bills of material (which describe the components of each item produced), cost standards (e.g., cost per pound of a given raw material), performance standards (e.g., labor hours for a manufacturing operation), expected scrap rates, etc.), and production capacity.
- Transactions waiting to be processed.
- Information stored temporarily as intermediate output, waiting for further processing.
- Environmental data.
- Archival information, such as financial data retained for legal purposes.

Before the original source document is keypunched, certain parts of it may require modification by a clerk. For example, the clerk may classify a sale according to the industry to which the customer belongs in order to provide sales analysis information (to select advertising media, say). In other cases some coding may take place—that is, the assignment of a standard (and normally compressed) representation of the information recorded in the source document. For example, state names may be assigned a standard two-letter designation (Massachusetts = MA, California = CA, etc.) and descriptive product information assigned a numerical code (e.g., red = 1, blue = 2). These functions may be performed at the original data collection point or automatically within the computer, but in some cases it is more convenient, accurate, or economical to do it as a separate clerical operation prior to conversion to machine-readable form.

Figure 9. Conversion of sales order into punched card form.

The card punch is the basic data collection device in many information systems. It provides a way of converting a handwritten (or typed) source document into a punched card that can then be processed by machine.
<table>
<thead>
<tr>
<th>Means of Connection to Machine</th>
<th>Means of Input</th>
<th>Means of Recording</th>
<th>Means of Sending</th>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most widely used, some go relatively slow input of punched cards into computer.</td>
<td>Key-punch or card punch, generally increases efficiency with keypunching. More correctable errors possible.</td>
<td>Manual key-punching, with hard copy output, data tape, or magnetic disk or drum.</td>
<td>Manual or electrically generated. Type or print.</td>
<td>Conventional card punch, remote terminal, optical scanning, key-punch.</td>
</tr>
<tr>
<td>Rigid, slow manual input, increases efficiency with keypunching. More correctable errors possible.</td>
<td>Usually limited to fairly high volume applications, due to high cost of input devices.</td>
<td>Automatic reading, with control to, by computer, output of machine readable code or data tape (or disk input to computer).</td>
<td>Not necessary, since original recording is machine readable.</td>
<td>Automatic setting of pressure, temperature, counts, etc.</td>
</tr>
<tr>
<td>Terminal is linked directly to computer, permitting use, in &quot;real-time,&quot; applications where efficiency of data collection is important. Since the computer can aid the human operator, by guiding the sequence of data collection, the data collection can be more accurately done at a higher speed.</td>
<td>Terminal is linked directly to computer, permitting use, in &quot;real-time,&quot; applications where efficiency of data collection is important. Since the computer can aid the human operator, by guiding the sequence of data collection, the data collection can be more accurately done at a higher speed.</td>
<td>Not necessary.</td>
<td>Not necessary.</td>
<td>Automatic setting of pressure, temperature, counts, etc.</td>
</tr>
</tbody>
</table>

- Redundant back-up information to guard against the loss of vital records.

The data base. The total collection of stored data is termed the data base of the organization. The data base provides a formal analogue of the organization and its environments. It is kept more or less current through periodic updating that adjusts the stored information to reflect new transactions.

Decisions based on the formal information system rely on the description of the real world contained in the data base; they are not based on the real world itself. The intent, of course, is to have the data base give a faithful enough representation of the real world that good decisions are made. Inevitably, however, the representation introduces distortions due to errors in data collection, delays in updating, gaps due to significant omissions, and all of the filtering and condensation that takes place within an information system.

Generally, there is some penalty associated with such distortions: decisions are not as good as they otherwise would be if the uncertainty caused by the distortions did not exist. Since an increase in the accuracy of the representation causes more money, the design of the data base always involves a compromise between accuracy and cost. See Figure 11.

Associations among data elements. The data base consists of a very large number of individual pieces of stored information; each such piece is termed a data element. A data element is the smallest amount of information that has meaning to the user. It is composed of contiguous numbers, letters, or arbitrary symbols.

In order for a data element to be of any use, it is necessary for the system to associate its value with a particular type of element and specific entity to which it refers. In Figure 11, for example, the data element "2.75" only has meaning when it is associated with the specific data element (unit cost) and a particular part (number 4221).

The data base incorporates a great number of associations among data elements. For example, all of the data elements pertaining to a given customer—his name, address, credit rating, accounts receivable balance, and so forth—are associated with one another. The easiest way to establish such associations is to store the data elements contiguously within a storage medium such as magnetic tape. A set of data elements associated in this way is termed a record, as shown in Figure 12.

Associations made through contiguous storage can also apply to larger groupings of data. For example, it is very frequently necessary to establish an association among a set of similar records; the set is then called a file. Thus, the set of employee records constitutes the employee file, and the set of inventory records constitutes the inventory file. These files may be stored on a reel of magnetic tape or in successive locations within a magnetic disk device. Files, records, and data elements are related hierarchically in the manner shown in Figure 13.

Not all desirable associations can be established through contiguous storage. For example,
Figure 11. The data base as an analogue of the real world.

At any point in time certain conditions exist in the real world—such as an inventory balance of five units of Part 4321. The data base portrays the real world by recording selected information. As events occur in the real world—the withdrawal of an item from stock, say—the data base is updated to reflect the new conditions. Errors in data collection, delays in updating, and other distortions may lead to a discrepancy between the real world and the data base analogue. Most routine decisions are based on data base information, and so some penalty may result if a discrepancy exists. In the Inventory example shown above, an error in the on-hand balance may cause a delay in reordering replenishment stock.

Figure 12. An item record.

The set of contiguous stored data elements describing a given inventory item constitutes an item record. The attribute to which each data element value refers is, in this example, implicitly defined by its relative position in the customer record: the first element gives the part number, the second gives the unit cost, and so forth. The program that retrieves information from the record must, of course, have some way of relating a data element value with its corresponding attribute. In some cases it is advantageous to explicitly identify the attribute to which a value refers by storing the attribute name (or perhaps an equivalent compact code) along with the value—by storing "PART NO" immediately preceding "4321," for example.

Figure 13. Hierarchical structure of the data base.

The data base exhibits a hierarchical structure. It is partitioned into files, which are composed of records, which are in turn composed of data elements.

we may need to associate a given customer's sales order with the inventory records of items included in the order. We would need a link of this sort if, say, we wished to determine the status of an order being held up by an out-of-stock item. Status information includes, among other things, the quantity on order from our supplier and the expected date of delivery. Since the item is not uniquely associated with a given customer or sales order, we cannot include detailed item information as part of the customer record; to do so would require the duplication of the item information with each customer record—clearly an undesirable solution.

We thus face the problem of linking noncontiguous records to establish association among them. Dealing with a rich variety of associations among data elements is one of the more important and difficult aspects of designing an information system. Ideally, we would like to be able to establish any link thought to be useful. Figure 14 shows examples of the types of association that we might want.

In practice, we may often ignore associations because of the cost and technical difficulties of establishing the link. Thus, for example, in a system for an insurance company we may not associate a given customer's homeowners policy with his automobile policy, or the fact that this same policyholder happens also to be president of a firm that pays the company a million dollars per year in
Logical and physical organization of the data base. Associations among data elements are matters dealt with in fixing the logical organization of the data base. Logical organization is concerned with the structuring of the data base into files, the content of each file (i.e., which data elements are grouped together and stored contiguously), the sequence of records, and the links across records.

Physical organization deals with the way in which the logical organization is represented in physical storage media. Often the data base is dispersed among multiple geographical locations; almost always it is split among a variety of storage media, such as magnetic disk, magnetic tape, punched cards, microfilm, and paper records. The distinction between logical organization and physical organization can best be explained by an example. Suppose we have a file of 10,000 employee records that are processed in ascending sequence according to the employee number. This set of records could be stored on punched cards, magnetic tape, magnetic disk, or virtually any other machine-readable storage medium; the logical organization remains the same in any case. The physical organization would, of course, be quite different if the files were stored on magnetic disk instead of punched cards. The cost of storage, efficiency of processing, and response time depend heavily on the choice of physical organization, even though the content of the records may remain the same. Insofar as possible, however, the users of stored information should be shielded from dealing with issues of physical organization so that they should primarily concern themselves with the logical organization that governs the information they can retrieve from the data base.

Physical storage characteristics. There are a few characteristics of physical storage media that have a particularly significant bearing on the system's performance:

- **Machine readability.** The ability of the computer to process stored information is obviously of great importance in a computer-based system. Nonreadable paper forms are often used as original source documents; afterwards they may be filled for a time or microfilmed for archival purposes. Technical documents and narrative reports are also typically stored in nonreadable form but are often indexed in machine-readable form to allow automatic retrieval. Other than for cases of this sort, virtually all of the stored media of interest to the systems designer are machine readable.

- **Off-line storage versus on-line storage.** Information included in the data base cannot be manipulated directly in its recorded form (e.g., on magnetic tape); instead, the physical storage medium on which it is stored must first be accessed in order to transfer the information into the computer where the actual processing takes place. If human intervention is required to access storage, the medium is said to be off-line. For example, a reel of magnetic tape is usually stored off-line. When records stored on the tape are to be accessed, the reel must be mounted on a tape unit. The tape can then be accessed by passing the tape over a read head capable of sensing magnetically recorded informa-

Figure 14. Associations among records.

Suppose the data base includes records on customers, sales orders, inventory items, purchase orders, and suppliers. An obvious need is to allow retrieval of records of a given type (customer records, say). The ability to establish associations across records of different types is also clearly desirable. For example, we would want to be able to associate a given customer (Customer B, say) with any outstanding (i.e., not yet delivered) sales order from this customer (Sales Orders X and Z in this case). Similarly, we would like to associate the items on a sales order with their corresponding inventory records (Items 2 and 4 associated with Sales Order X, for example). Links between an inventory record and any purchase order for the item, and between a purchase order and the supplier to whom it is issued, would also be desirable. Some of these associations can be established by storing related records together— all records of a given type, say, or records that "belong" uniquely to a given record (as Sales Orders X and Z belong to Customer A, for example). When no such unique relationship exists, however, associations must be made through some form of cross-reference. With most storage devices, processing noncontiguous cross-linked records is distinctly more costly than processing records stored contiguously.

7 There are numerous stories that illustrate the hazards of ignoring such associations. One such story concerns a bank that bounced a small check written by a little old lady who happened to have over a million dollars in a trust account with the bank. There was no link between her checking account and trust account and so the automatic rejection of the check was made solely on the basis of a delayed balance in the woman's checking account. As a consequence, the bank lost the trust account and the EDP manager lost his job.

8 Most of our concern will be with data stored in a form that can be automatically retrieved and manipulated—which, with today's technology, is largely confined to magnetic media such as disk or tape.

9 The physical organization is said to be transparent to the user if changes in physical organization are not apparent to him—i.e., do not affect the way he stores or retrieves records.

10 The computer itself has some primary storage as one of its components. This is used for storing programs being executed and data being manipulated. Because of its limited size and very high cost, primary storage is never used permanently for any portion of the data base. The data base resides in some form of auxiliary (or mass) storage, such as tape or disk, that is inexpensive enough to justify its permanent use for a given type of record. A data base record must then be read from auxiliary storage into primary storage before it can be processed. If any changes are made during processing, the updated record must be written back into auxiliary storage. Figure 15 illustrates the distinction between primary and auxiliary storage.
Figure 15. Primary versus auxiliary storage.

The Central Processing Unit (or CPU) consists of an arithmetic/logical unit, where actual data manipulation takes place; primary storage, where currently active programs and data are stored; and input/output channels, which manage the transfer of data between primary and auxiliary storage. Auxiliary storage devices, such as magnetic tape and disk, retain programs and data that are not currently active—i.e., that are not currently being executed or manipulated. If a nonactive program is to be executed, it must first be transferred through an input/output channel into primary storage (under control of the operating system). In a multiprogramming system, as shown above, two or more programs may exist simultaneously in primary storage and be executed concurrently.

- Storage that can be accessed without human intervention is said to be on-line. A tape reel, once mounted on a tape unit, thus becomes on-line storage because no further intervention is required, i.e., the tape can be scanned under control of a program without assistance from the computer operator. Most magnetic disk devices permit the removal of the disk packs on which the actual recording is made. Thus, disk storage can be either off-line or on-line. Typically, however, many of the disk files are kept permanently mounted to permit continuous on-line access.

- Sequential access versus direct access. Some storage media can only be accessed in a fixed, sequential fashion. For example, punched cards can only be read one after the other in their physical sequence in the deck. Similarly, a magnetic tape can only be read by scanning it serially along its length (but, unlike the deck of punched cards, the reading can usually be performed in either direction).

- In contrast to sequential storage media, direct access media allow access to a given portion of the file (a particular record, say) without scanning over all portions intervening between the desired record and the one last read. The most widely used direct access storage is magnetic disk. With this device it becomes feasible to read records scattered randomly over the disk surface. The obvious advantage of this is that it reduces the time required to obtain information from auxiliary storage.

- Access time and transfer rate. Storage media differ greatly in their performance. Access time is defined as the time it takes the computer to bring a desired record into primary storage from auxiliary storage. It is normally of interest only in connection with direct access devices; for these, access time varies from a few milliseconds to over a second. The transfer rate is the rate at which information can be read from auxiliary storage into the processor. This is the performance specification of greatest interest for sequential access media, since it governs the rate at which records can be scanned. Many tape and disk devices are capable of transferring information at a rate of several hundred thousand characters per second.

- Volume of data. Off-line storage has virtually unlimited capacity; it depends only on the space available to maintain the storage library. The size of on-line storage is more restricted. Each storage device has a fixed upper limit. One popular size disk storage unit, for example, has a maximum capacity of 253 million characters, while another has a capacity of 800 million. A number of these devices can usually be attached to a given computer, but cost often imposes a serious constraint. Accordingly, fast access to a given type of record must provide substantial benefit if the record is to be retained on-line.

- Erasable versus nonerasable storage. Some media can be used repeatedly; unwritten data can simply be erased and new information recorded in its place. Magnetic media are erasable. Some other media are not, however. For example, punched cards cannot be erased and used again; information is recorded permanently. Photographic media also provide a permanent record. Nonerasability can be a great advantage (to provide a legal record, say, or to insure against accidental erasure), but it also reduces flexibility and does not permit the economy of using the medium over and over again.

- Cost. In most cases the selection of storage characteristics comes down to costs. Almost any level of performance can be obtained at a price. The trick for the designer is to choose a mix of storage media that gives the best balance between cost and performance. This will almost always result in the use of a hierarchy of storage devices, as shown in Figure 16.

4.3 Retrieval. What is stored in the data base is eventually retrieved—or at least this should be the expectation. Information is retrieved to serve routine operating requirements and management needs. The efficiency, flexibility, and response time of retrieval have a major effect on the performance of the system.
Figure 16. Physical storage hierarchy.

No one storage medium meets all requirements in terms of cost and performance. To get around this problem, the data base is divided among a hierarchy of media that offer varying performance specifications at corresponding prices—for example, about $10 per month for a million characters of on-line disk storage and a few cents per million for off-line tape storage. The decision as to where a given record within the storage hierarchy should be stored depends on the urgency and frequency with which the record is accessed, its size, and similar factors.

Most of the retrieval is required for routine transaction processing. Virtually all transactions entering the system call for access to one or more data base records. For example, a sales transaction may require retrieval of the customer's record and the record of each item included on the order. In most cases groups of transactions are batched together and processed in a predetermined sequence (alphabetically by customer name, say); this is called batch processing (see Figure 17). In other cases the retrieval takes place from on-line direct access storage soon after the transaction enters the system; this is called random (or direct) processing (see Figure 18).

An important characteristic of a system that strongly affects the selection of storage media and processing techniques is the response time to be provided by the system—that is, the time it takes to react to a significant event or request for information. At one extreme is the so-called on-line real-time system that maintains more or less continuous monitoring of the environment and updates the data base within a matter of a few seconds or less. Such a system may be very closely involved with detailed operations, as one finds, for example, in airline reservation systems, process control, and air traffic control.

Figure 17. Retrieval of data base records with sequential processing.

Transaction processing requires matching of transaction data with the corresponding data base records. An order for item 1073, for example, requires the retrieval of the inventory record for that item. In the case of sequential processing, transactions are batched processed in the sequence of the corresponding data base records. These records exist in sequential order, based on one of the data elements in the record (ascending sequence of item numbers in this example), which is called the key of the file. Prior to processing, the batch of transactions is sorted into a sequential transaction file based on the same key. Each transaction can then be matched with its corresponding data base record with a single scan (or pass) of both files. Sequential processing permits the economical use of a sequential storage medium such as magnetic tape.

Most systems are not of this type. The data base may be updated in batch fashion fairly frequently—once a day, perhaps, and often much less frequently. When the environment changes relatively slowly and information is not needed in a hurry, batch processing gives adequate control at low cost. The trend, however, is toward systems that provide short response times in order to control more closely day-to-day operations and create a closer rapport with decision makers.

Retrieval of information to serve management's needs often imposes more complex requirements than the retrieval associated with transaction processing.
### Transactions (in order of arrival)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1073</td>
<td></td>
</tr>
<tr>
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<td>2923</td>
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<td>3</td>
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</tr>
<tr>
<td>6</td>
<td>3715</td>
<td></td>
</tr>
</tbody>
</table>

### Data Base

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>7</td>
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<td></td>
</tr>
<tr>
<td>9</td>
<td>1073</td>
<td></td>
</tr>
</tbody>
</table>

Figure 18. Retrieval of data base records with random processing.

If transactions are processed randomly, the processing takes place in the order of arrival (or perhaps on the basis of some other priority rule); in particular, they are not processed in the sequence in which the corresponding data base records are physically stored. In this example the transactions are processed in order shown by the circled numbers. The data base records themselves may be stored either sequentially or randomly throughout a storage device. Random processing is only feasible when the data base records are stored in a direct access device that avoids having to scan all records until the desired one is reached. Instead, the address of the data base record corresponding to a given transaction is found by the program by searching an index or through an address calculation scheme. Once the address is found, the record is read from the direct access storage device into the computer's primary storage, where it is then available for processing.

Management generally asks for more than the mere extraction of information from the data base. In most cases data elements must be processed in some way before the information is presented to the user. Processing may require nothing more than aggregating or counting; or it may, on the other hand, require elaborate calculations of the sort one finds in most decision models. As the complication of the retrieval system increases, serious problems arise concerning such matters as the identification of desired information, the indexing of data base records, the means of establishing the logical and physical organization to meet information requests at an acceptable cost, and provision for security to guard against accidental destruction or unauthorized access of the data base.

#### 4.4 Computation

Any manipulation of data involves some form of computation. The most obvious form is arithmetic computation. The calculation of gross pay, for example, requires the multiplication of the hours worked times the rate of pay. The calculation of summary data, averages, or updated inventory balances also calls for arithmetic operations.

Most routine data processing requires relatively few arithmetic calculations. In a typical program considerably less than ten percent of the operations performed may be arithmetic; the remaining ones deal with input and output, internal movement of data, comparing one data element with another, preparing data for printing, and so forth. Often the total elapsed time to perform the computation is largely governed by input/output time rather than the time required by the central processor to perform internal manipulation of data.

The preparation of management information may more nearly tax the internal capacity of the computer. A considerable amount of computation—both arithmetic and nonarithmetic—may be required when the computer is used as a filter between the data base and the manager. The computer may have to scan large quantities of data and apply sophisticated selection criteria in order to prepare condensed information useful for decision-making purposes.

The pronounced trend toward greater formalization in decision making leads to the substitution of computation for human decision making. When this occurs, computational requirements begin to soar. For example, in applying linear programming—a widely used technique for calculating optimal decisions—a large problem may consume several hours on a very fast computer and require the execution of billions of instructions. Man-machine models of the sort sometimes used for higher level decisions, also may impose huge computational requirements on the system.

#### 4.5 Display

The display function provides a connection between the computer and the user. The display of information to the user is a critical aspect of the system. Information is presented for use in routine operations, in response to inquiries, and for management decision making. Effective display that aids the human in his perception of relevant information can contribute substantially to the usefulness of the system.

It is important to note that not all outputs from the system are displayed. In a process control application, for example, outputs may directly activate valves that control flow rates. A large proportion of outputs may be stored in the data base without being displayed in detailed form. This becomes all the more true as the formal system takes on an increasing share of the organization's routine activities. Display in such a case may be confined largely to summary information used to monitor the performance of the system.

**Visual display.** Easily the most common way to present information is through visual display; audio display has only limited application, and the other human senses (smelling and feeling) are virtually never used in a formal information system. Visual display predominates so completely because of the convenience of written reports and because the amount of information that can be perceived visually vastly exceeds the "channel capacities" of the other senses.

There are two basic types of visual display—alphanumeric and graphical. An alphanumeric display uses only a limited number of standard characters—the alphabet (often only upper case, but sometimes lower case as well), the numerals, blanks, and certain special characters such as . , $ + - * / ( ). Each character can be placed only at a particular discrete position on the display surface. For example, a standard printer has 132 print positions along one line of print, and a teletypewriter has 72 positions.

Alphanumeric output from a computer-based system is often displayed in tabular form; only in relatively rare applications, such as document retrieval, does one find a display presented in a narrative format. A tabular report displays information in the form of columns of alphanumeric characters. Each column is normally labeled with an identifying heading, as shown in Figure 19.

The tabular format has a number of important advantages. It is:

- Relatively inexpensive to use.
- Widely familiar and well understood.
- Capable of showing information with what-ever precision is desired.

Tabular reports often suffer, however, from a major disadvantage: complex relationships among variables are difficult to perceive when they are presented in tabular form. A reader of the report in Figure 19, for instance, must study it carefully to discern the essential facts of the situation.

A graphical display often overcomes this problem. A graph can easily show overall relationships among several variables. Figure 20, for example, shows in graphical form the same information presented in tabular form in Figure 19. The inter-
MONTHLY SALES, PRODUCTION, AND INVENTORY REPORT

PRODUCT—125A COMPRESSOR

MONTH—MAY 1972

<table>
<thead>
<tr>
<th>MONTH</th>
<th>PLAN</th>
<th>ACTUAL</th>
<th>DEVIATIONS</th>
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</tr>
<tr>
<td>DEC</td>
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<td>6613</td>
<td>812</td>
</tr>
</tbody>
</table>

Figure 19. Sales, production, and inventory report in tabular format.

The report gives cumulative sales, production, and inventory information for a specific product. On the basis of this management can assess how well actual performance conforms to the plan. Question: Is this product under control? If not, what appears to be the problem?

relationships among the variables, rather than their absolute value, is the thing of primary interest for assessing performance. For most of us, essential information can be assimilated from the graph very much more easily than from the equivalent tabular report.

Effective display is particularly essential in fast-response, man-machine systems in which the human must gain a quick grasp of the situation. In an air traffic control system, for example, fast decisions are sometimes called for in an emergency. Time lost in pouring over a tabular display would be intolerable under these circumstances. Even when an urgent decision is not required, speed in comprehending a display permits the user to browse through the data base and explore more alternatives than he otherwise could.

One of the advantages of a graphical display is its flexibility. Information can be coded in a great variety of ways:

- Standard alphanumeric characters.
- Abstract shapes (e.g., the shape of an airplane in an air traffic control system).
- Line width, length, or type (e.g., solid versus dashed lines).
- Color.
- Size.
- Position or orientation.

Although the graph provides low precision, it is perfectly adequate in this case to convey essential information.

- Dynamic effects (e.g., flashing or moving symbols).

Despite the compelling advantages of graphical display, it has not been used widely (compared to tabular reports). Some of the reasons for the limited application are:

- The high cost of preparing high-quality graphs.

Figure 20. Sales, production, and inventory plan in graphical form.

This display shows planned and actual values for production, sales, and inventory—a total of six interrelated variables. One can perceive at a glance the planned versus actual performance—something that was not possible with the tabular display. For example, the graph shows clearly the seasonality of sales, the planned changes in the production rate, the increase in sales over the forecast (beginning in February), the failure to meet the production plan (in April), and the drastic decline in the rate of sales (due, perhaps, due to a shortage of inventory). Although the graph provides low precision, it is perfectly adequate in this case to convey essential information.
- Management's lack of familiarity with graphical information.
- The lack of attention paid to management's needs, rather than data processing efficiency.
- The lack of precision in representing numerical information.

The situation is changing. The cost of preparing graphical displays is coming down substantially. Interest is growing on the part of managers and designers in using graphical display for applications calling for effective perception and comprehension. The great flexibility of graphical display and information retrieval is being tapped to allow users to gain both an overall view of things and, through selective inquiry, precise detail when a decision requires it.

Equipment manufacturers offer a wide selection of visual display devices. They differ in a number of important characteristics:

- Transient display versus hard (i.e., permanent) copy. A printer or teletype gives permanent printed output. A display using a cathode ray tube (CRT)—a TV-like device (shown in Figure 21)—is transient; it is erased when the next display is presented. Some CRT's allow hard copies to be prepared (for example, through photographic or Xerographic means).

- Alphanumeric versus line drawing. An alphanumeric device allows a limited character set to be displayed in discrete positions (Figure 22); a line drawing device permits high-resolution graphical output (Figure 23). An alphanumeric device can be used to produce graphical output, as shown in Figure 24, but resolution obviously suffers.

- Amount of information that can be displayed at one time. The capacity of the device limits the number of characters per line, lines per display, and the fineness of resolution of graphical information.

- Rate at which displays can be presented.

- Special features, such as editing capability, ability to modify the display (e.g., rotate or change the scale of a graphical display), and associated input devices (e.g., keyboard or pointer).

Audio display. A discussion of display would not be complete without some mention of the one alternative to visual display. In certain circumstances it is very convenient to display information in audio form. A universally available display device, the telephone, makes it possible to obtain information from almost any remote location. Audio display has been used in a number of inquiry applications, providing such information as stock market quotations and inventory balances.

Suppose, for example, a subscriber to a stock market quotation service wishes to know the latest price for a particular stock. He keys in (usually on a "Touch-Tone" keyboard) the telephone number that connects him to the system. He then punches a code that identifies the stock about which he is inquiring. The computer analyzes the inquiry and retrieves the latest price from the system's data base (which is updated as market transactions occur). It then composes the appropriate audio message. It does this by retrieving recorded words from an audio storage device. If the price were, say, 56-1/4, it would transmit the words "fifty-six dollars and one-quarter." The recorded vocabulary must include all words, numerals, and fractions used in stock market trading.

The principal advantage of audio display is the wide availability of the telephone and its low cost and ease of use. The chief disadvantage is the limited amount of information that can be displayed.
The human can sense visual information at a much higher rate than audio information. An audio message should be restricted to a relatively short, simple message using a limited vocabulary. One obviously could not, for example, use audio display to provide the information shown in the tabular report of Figure 19 (although selected portions could be so displayed).

4.6 Data communications. A number of reasons exist for moving data from one location to another:

- Data are often collected originally at points remote from the point of processing, and so somehow they must be moved to the processing location.
- Operational and planning information—in the form of text messages or coded data—must be transmitted among geographically dispersed units of an organization.
- Remote users request information stored in a central file.
- Remote users require access to a central computer.
- Different computer centers communicate with one another in order to gain economies of scale, balance loads, obtain back-up capacity, use specialized facilities, or share data.

Early computer-based systems rarely had significant communications components; now most new systems are designed to include such capability. This has extended the scope of the organization's coordination and brought computer resources to the remote user.

Often the most effective way to communicate is by physically transporting the storage medium on which data are recorded. In the earlier example of Able Markets, store orders were brought to the central warehouse in the returning truck that delivered the day's shipment. This offers the advantages of economy, reliability, convenience, and reasonable speed. Mail, freight, or special courier service also provide means of transporting data.

The alternative to physical transport is electrical transmission. Each of the Able stores can be equipped with a terminal that transmits store orders prepared in machine-readable form (e.g., paper tape or magnetic tape cassette). Transmission to the central warehouse can be made over the existing telephone network at regular long-distance (or local) rates. Initiation of transmission requires no more than the standard procedure for placing a telephone call—i.e., dialing the appropriate number and waiting for the called party to answer. The process of initiating and supervising the transmission can be handled manually, or it can be made completely automatic (depending on the transmitting and receiving terminal devices).

In the Able example, rapid data communication can reduce the delivery lag from two days to one. Orders can be entered by a key operator, be processed in batch fashion before the end of the normal working day, and then be filled by the warehouse and made ready for delivery before the beginning of the next day, as shown in Figure 25.

A reduction in delivery lag brought about by rapid communications permits a reduction in store inventory (or perhaps an improvement in service). This obviously is of some value to the firm. Offsetting the benefits is the added cost of the terminals and communication lines. Choosing the means of communication can (in this case) be made on the basis of a fairly straightforward analysis of costs and benefits.

The trend in designing a comprehensive information system is certainly toward greater use of electrical transmission of data. Data transmission is becoming less expensive, more reliable, and capable of meeting a wider variety of needs.

After making the basic decision to include communication components in a system, the designer faces a bewildering number of alternatives. Some of the principal characteristics that must be considered are the following:

- Volume of data transmitted between all points in the communications network. Special attention must be paid to volume during peak periods, since this generally fixes the level of capacity required.
- Degree of urgency for different classes of message. If messages can be delayed, they can be transmitted during off-peak periods in order to lower capacity requirements (and hence cost).
- Type of input. Data can enter the communications network from a manual keyboard, from off-line machine-readable media (often paper tape or punched cards, with growing interest in magnetic tape cassettes), or from a direct computer-to-computer link using on-line storage.
- Type of output. Output can come in the form of low-volume hard copy (e.g., a teletypewriter), a high-volume hard copy (e.g., a printer), a CRT display, off-line machine-readable media, or on-line storage.
- Reliability requirements. A reliable system is one that functions normally at a high proportion of the time. Certain real-time systems demand very high reliability because of the heavy dependence placed on them by ongoing operations. More conventional systems, on the other hand, can tolerate occasional breakdowns in the communications links without suffering major penalties. For example, if Able Markets were to transmit store orders to the central warehouse, a failure in communications lasting a few hours would probably not cause major disruptions. Not surprisingly, the best things in life are not free: as reliability goes up, so too does...
the cost of providing it.

- Accuracy. Even when a communication link is functioning normally, it will make occasional errors. Accuracy is measured by the probability that the data received at the output terminal is identical to the data transmitted by the sending terminal. Various techniques exist for obtaining almost any desired level of accuracy, but at an increasingly high cost as perfection is approached.

5. Data Base Management

The data base is increasingly being recognized as one of the organization's most vital resources. A company such as Able Markets could scarcely stay in business if its data base were lost. The processing of a store order, for example, requires access to the store and inventory files (and, in some cases, supplier files). In addition, most of the management decisions made within the organization rely on information coming from the data base.

The information system must allow retrieval of desired information within a suitable response time. The data base may be very large, with complex relationships among data elements. It must be protected against destruction or unauthorized access. The cost of data processing is significantly affected by the efficiency of data base access. For all these reasons, dealing with access to the data base is one of the most critical and difficult aspects of designing a system. The processing tasks associated with such access collectively fall within the data base management function, as described in Figure 26.

![Figure 26. Role of the data base management function.](image)

The data base management function provides an interface between the data base and various sources and uses of data. One major task is handling information inputs and inquiries coming directly from users. The bulk of inputs and outputs, however, are connected with routine application programs. In actual practice the data management function is rarely handled by a single, separate system program; instead, portions are dispersed among application programs and general purpose system software.

5.1 Requirements of the data base management function. The data base management function basically deals with storage and retrieval. Connected with these basic functional tasks, however, are a number of requirements that can usefully be grouped together and considered as a whole. They are as follows:

- Interface with application programs. Virtually all application programs require access to the data base. Efficiency of access, as measured by the resources tied up in transferring records between primary and auxiliary storage, becomes a major issue when dealing with a frequently used application program that accesses a large number of records.

- Ad hoc inquiries. A large number of decisions must be made within an organization. Most are routine decisions whose information inputs can be anticipated and specified in advance. Application programs can thus be written to satisfy such information requirements.

- Some of the most important decisions, however, cannot be anticipated, at least not in detail. A problem may arise, the solution to which requires information not available from routine, periodic reports. Very often the necessary raw data exist within the data base; what is needed is a means of retrieving the data and operating on them to produce specified information. In order to be useful the information should be available within a relatively short time period (up to a day, perhaps) and without the great effort usually required to write a special-purpose program.

- The data management function should therefore include a user-oriented retrieval language for specifying ad hoc inquiries. For example, a personnel manager wanting the number of women making over $10,000 a year might write the inquiry, PRINT COUNT WHERE SEX EQUALS FEMALE AND SALARY GREATER THAN 10000. After this has been read (through a punched card reader or a remote teletype terminal, say), the data base management system translates it automatically into the detailed program that performs the specified retrieval and computation.

- Data base security. The data base is an invaluable resource, and so it must be protected. Three aspects of security need to be handled:

- Validity of data entering the data base.

- Privacy, to guard against unauthorized access to portions of the data base.

- Backup, to guard against the catastrophic loss of major portions of the data base.

Suitable validity can be achieved by subjecting incoming data to various error checks—to test, for example, that a transaction data element falls within "reasonable" limits. Privacy can be achieved by associating with each segment of the data base (the payroll file, say) a list of users who are permitted access. The system should make a distinction between access to read a segment and access to modify it; for example, a nurse in a hospital may be allowed to read the contents of a patient record but not be allowed to modify it. Backup protection is gained by storing a duplicate copy of the data base so that it can always be reconstructed if something happens to the original.

Flexibility. In order to respond to changing needs, it should be possible to modify the logical or physical organization of the data base without causing major disruption. For example, the system should permit the addition of new records to a file or new data elements to a record. New associations among records should also be allowed. Transfer of a given file from one physical storage medium to another should be a relatively simple matter.

A number of factors call for flexibility of this sort. For one thing, the output requirements of the system change over time, giving rise to modifications in the data base. A new city tax, for example, may require the addition of data elements to the payroll record of each employee; or the sales manager may find it useful to add an industry code to each customer record to permit sales analyses by industry. Flexibility is also required to exploit the latest technology. For example, the availability of a new magnetic disk storage device, which offers improved price or performance, may make it desirable to replace the existing disks with the new ones.

5.2 Realization of the requirements. Few existing information systems meet all of the above requirements of the data base management function; this is, in fact, one of the principal deficiencies of most systems. Current systems focus on meeting the needs of application programs and satisfying the
Most pressing security requirements. Very often little provision is made for dealing with ad hoc inquiries or providing flexibility.

Normally data management is handled largely on an application-by-application basis. Each application program is responsible for such matters as error checking. If it exists at all, the satisfaction of inquiries. Certain common tasks, such as the control of detailed input/output operations and the allocation of physical storage devices, are handled in part by generalized system software.

Nevertheless, data management functions can easily account for 25 to 50 percent of the programming effort required to implement an application program.

The trend is toward the development of a common software package to handle all data base management functions, as discussed in Figure 27. This approach offers a number of extremely important advantages:

- It avoids the cost of duplicate development of data base management capabilities within each separate application program.

- If duplication is avoided, it becomes feasible to devote sufficient resources to the task of developing a comprehensive set of data base management functions. Individual application programs cannot possibly justify the effort required to do this.

- Elimination of duplicate data management functions also reduces the total size of all programs and thus reduces storage requirements.

- The separation of application programs from data base management achieves considerable flexibility. A change in an application program may have little or no impact on the data base, and vice versa.

- A common system promotes standardization of file organization and data definitions, thus facilitating the exchange of information among different parts of the organization.

- The development of a common data base, which is shared by all programs and users, absolutely requires a common data base management function. By definition of such a system, no one program "owns" any segment of the data base; therefore, no program can dictate how a given segment is accessed and protected. A common software program must exist that guards the integrity of the data base and serves as a "traffic cop" to multiple programs or users access the data base concurrently.

These advantages come at a cost. The development of generalized data base management packages has proven to be exceedingly difficult and costly. Significant progress has been made, but much remains to be done. Because of their generality, these packages exact some penalty in processing and storage efficiency. This can be a serious limitation in the case of high-volume application programs.

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6.1 Components of a system. Despite the popular use of such terms as "integrated" or "total" information system, we must recognize that such a system is far from being a single, monolithic thing. As a practical matter the system must be broken down into separate subsystems. The subsystems are, in turn, broken down into finer components. The aim is to identify more or less independent parts that can be designed and operated without detailed attention being paid to all other parts. Only in this way can the system be made comprehensible and manageable enough for the designers to cope with its great complexity.

We will call each of the independent parts a module. It is difficult at this point to define a module with much precision; think of it simply as a major processing task that is relatively independent of other parts of the system. Thus, our system may include a module for payroll, one for inventory control, one for production scheduling, and so forth.

The partitioning of the system into modules, and the interfaces among them, establishes the structure of the system. Each module is defined in terms of its inputs and outputs. Interrelationships among modules depend on the way in which one module receives or provides information to other modules.

An information system can be structured in an infinite number of ways, and there is no (known) best way. Some structures clearly do not make much sense (such as combining engineering functions with stockholder record keeping); these can be dismissed without further consideration. But there still remains a vast number of legitimate alternatives. A designer must decide, for example, whether factory cast accounting functions should be included in the production control module or combined with other accounting activities.

Structural choices of this sort are among the most important decisions facing the designer. They have a major impact on the following goals of the system:

11 Blumenthal (1969, pp. 40-45) discusses the concept of processing modules.
- Ability to meet routine operational needs of the organization.
- Ability to meet information requirements for decision making.
- Efficiency in computing, data collection, and communications.
- Simplicity and reliability.

Unfortunately, these goals often conflict, and so one must choose a suitable compromise among them.

6.2 Structuring the system along organizational lines: Various approaches can be followed in structuring an information system. A common approach is to structure along organizational lines. Suppose, for example, that a manufacturing firm is composed of three major divisions—Consumer Products, Industrial Products, and Defense Products. Each division is, in turn, divided along the functional lines of marketing, engineering, manufacturing, personnel, research, and financial administration. The information system for such a company could follow these same lines. An independent system could be developed for each division and consist of modules conforming to departmental boundaries, as in Figure 28. These boundaries remain relatively stable and presumably correspond to the way most activities are carried out—i.e., major operations are oriented along product lines, while operations within a product division follow the functional boundaries of marketing, manufacturing, etc.

This approach, though common and plausible, creates difficulties. Independent development of separate systems results in considerable duplication of design effort. A more serious flaw is that processing and decision making needs of the firm do not always coincide with existing organizational boundaries.

Even if the organizational structure adheres closely to the way most of the firm's activities are performed, there is no reason to suppose that all activities and decisions should follow the same boundaries; some of them inevitably should be dealt with along other lines. For example, the receipt of a customer order may have an obvious impact on marketing, manufacturing, and accounting (and perhaps engineering and personnel as well). An information system conforming strictly to departmental boundaries has difficulty in dealing with interdepartmental activities. Decision-making information along lines other than existing boundaries—e.g., a sales analysis report organized by geographical location rather than by product—would likewise be difficult to obtain unless provision were made in advance to exchange information across boundaries using a common coding scheme.

6.3 Structuring along operational lines: We see that a strict adherence to organizational boundaries unnecessarily restricts the information system. An alternative approach is to ignore these boundaries and to concentrate instead on actual operational functions. One such function, for example, could be the logistics subsystem. A study of the requirements might conclude that the system should be structured in the way shown in Figure 29. This structure does not conform strictly to organizational boundaries (although, not surprisingly, there is certainly some correspondence).

This approach raises some serious problems of its own. One of them is lack of management support. A structure that crosses existing responsibilities

Figure 28. An information system structured according to organizational boundaries.

The structure of an information system may be designed to conform closely with the structure of the organization itself. A firm decentralized by product group, for example, might have a separate system for each division. Subsystems serve functional departments. The financial subsystem might include, for example, the billing and accounts receivable functions associated with customer orders. The manufacturing subsystem might be responsible for scheduling the actual production and shipping of customer orders.

Figure 29. Structure of a logistics system.

This illustration shows a simplified and abbreviated logistics system for a firm producing a standard (i.e., noncustom) product. (Related modules outside of the logistics system are shown by dashed lines.) The processing functions tend to cross organizational boundaries. For example, the production control module may collect production data used in payroll calculations, rather than requiring the payroll module to collect all of its own input data.
ties cannot easily be initiated by any one of the executives whose functions are affected. A lack of understanding, or even open hostility, frequently accompanies an attempt to implement such a system. What the technician may view as a simplification, the manager may regard as an invasion of his responsibilities.

Even if a manager supports the concept of a system that crosses existing departmental boundaries, he will still rightly insist that any new system provide the type of information that he needs to carry on his own job. Since the bulk of his decisions probably fall within the purview of his own department, it is necessary that the information system recognize the existing boundaries in order to provide information organized by management responsibility. For example, a new-wide logistics system must provide the following types of information:

- Sales analyses by product groups and sales territories.
- Production analyses by product group and manufacturing plant.
- Cost analyses by product group and resource input (e.g., labor class, material, capital equipment).

6.4 Structuring along data processing functions. Another problem arises when designers focus on either organizational responsibilities or operational functions. Each of the resulting modules has associated with it all of the information processing functions discussed earlier—data collection, storage, retrieval, computation, display, communications, and data management. Many of the modules have common information processing requirements. The possibility of combining some of the processing functions should therefore be considered in choosing a structure for the overall system. For example, a single communications module might be implemented to serve the needs of logistics, accounting, and other operational subsystems.

6.5 Multidimensional structure. We have thus identified three possible approaches to structuring the information system:

- Partition by existing organizational boundaries.
- Partition by operational functions.
- Partition by information processing functions.

Any one approach leads to some undesirable consequences. The alternative is to consider all three simultaneously. This results in a three-dimensional partitioning of the system, as shown in Figure 30.

Each cell in the resulting partitioning can be regarded as the lowest level building block for constructing the information system. A given structure is defined in terms of clusters of these cells that form the processing modules comprising the system. The characteristics of a system depend on the particular clustering chosen.

The basic issue facing designers is the compromise between independence and integration of the system's components. Independence is achieved by fragmenting the system into small modules and isolating them by restricting the amount of communication that cross module boundaries. For example, the order entry module could collect its own data and maintain its own portion of the data base independent of, say, the accounting system. The result would be a series of relatively simple modules with little overall integration or sharing of resources.

A high degree of integration is achieved by collapsing many of the basic building blocks into a few major modules and facilitating communications among these modules. For example, the order accounting functions associated with manufacturing operations might be included within the production control module, and significant information required in separate modules could be communicated by passing information among the modules or by sharing a common data base.

The seeming economy of such coordination is purchased at a drastic increase in complexity. Complexity, in turn, adds to the time and cost required to implement the system and subsequently increases the risk of failure. Some integration is clearly desirable and feasible. The trick is to know the best way to combine the basic building blocks—and when to stop.

Integration can proceed along any of the dimensions we have discussed—i.e., across organizational boundaries, operational functions, or information processing functions. In Figure 31, for example, some of the computational functions are combined to produce partial integration. Integration of the computation associated with financial control takes place across organizational boundaries, giving each division the same corporate-wide module. Integration of logistics and cost accounting stays within organizational boundaries (Consumer Products Division, say) but crosses the boundaries of these operational functions. Other forms of integration should similarly be investigated. It is conceivable, for example, that a single corporate communications system should be developed, thus integrating that information processing function across both organizational boundaries and operational functions.

7. Decision Making Within the Organization.

Decisions take place throughout an organization. At the lowest level the decisions deal with such routine matters as the size of an inventory replenishment order, the choice of job to assign to an idle machine, the insurance premium rate to charge for a renewed homeowners policy, or the assignment of classrooms to course sections in a university. At the level of middle manager, decisions become less routine and have longer run consequences; he deals with such issues as the quarterly production plan, the advisability of certain classes of insurance risk, approval of copy for the next month's magazine advertisement, or selection of a plant superintendent. The highest level deals with the fundamental decisions that shape the destiny of the organization—choice of its basic goals and structure, determination of sources and allocation of major resources, selection of activities to be pursued, assignment of managerial responsibilities, and similar long-term decisions.
well defined; in fact, more than three levels exist, with only fuzzy boundaries between them. Nevertheless, the three-level scheme allows us to describe the general characteristics of decisions that occur at different levels in the organization. Figure 32 summarizes the different characteristics.

It can be seen that the strategic level is concerned with the big picture: broad, long-range plans that do not change substantially from month to month and that guide the long-term behavior of the firm. From the point of view of the information system, strategic decision making presents special difficulties. Decisions at this level tend to be highly unstructured—i.e., hazy, vague, and ill defined (Simon, 1960). Precise rules cannot be formulated for dealing with such problems, and so the strategic manager cannot look for much aid from formal decision models. In fact, the systems designer can count himself fortunate if he can meet a significant portion of the strategic manager's needs for basic information. The unpredictable nature of strategic information often forces the manager to resort to informal sources—personal contacts, casual reading, and the like.

The tactical level deals with much more clearly defined problems. Its general task is to translate strategic decisions into more operational form. The objective of the translation is fairly straightforward—namely, to achieve the strategic plans as economically as possible. Compared to strategic plans, tactical plans are more detailed, extend over a shorter time horizon, and are modified more frequently in response to changes in the environment.

Since tactical decision making is considerably more structured than the strategic, formal information systems can play a larger role. Indeed, for some (low level) tactical decisions, the process can be completely specified in the form of an optimization model. Even when this degree of formalization is not feasible, the information system can often furnish significant help to the human decision makers. The aid can vary from handling ad hoc inquiries to a man-machine model that allows the human to pose an alternative plan (e.g., a production schedule) and receive from the computer a prediction about the consequences of the plan (e.g., production costs and the probability of an inventory shortage).

At the operational level things become even more structured. Many activities are completely spelled out in great detail (or programmed, to use Simon's term). Some of the rules or procedures may be expressed in the form of a computer program and require no human intervention at all. Even when human decision making is involved, information requirements may be predictable enough to allow standard periodic reports. Activities at the operational level, unlike the higher levels, tend to be detailed and fast moving. The information to serve in this environment must be correspondingly detailed, accurate, and timely.

A concrete illustration might clarify the distinctions between the three decision levels. Suppose we return to the previous example of Able Markets. Setting the aggregate inventory level within the firm certainly should be regarded as a strategic decision. This single class of asset may account for as much as half of total assets. The level of inventory has a major impact on working capital requirements, level of service, and the cost of physical distribution.

At the tactical level the aggregate inventory decision is translated into an order point and order quantity for each individual item. The objective should be to determine the decisions that provide the best balance between service and reorder cost while staying within the aggregate inventory constraint set at the strategic level. These tactical decisions are then carried out at the operational level. When orders from the stores bring the warehouse stock balance of an item below its order point, a replenishment order for the specified quantity is generated by the system. The order is then sent to the appropriate supplier (usually after human review).

8. Information Flow Within the System

We have seen that an information system is composed of a collection of modules. Each module has certain inputs and outputs. The source of the

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Anthony (1965, pp. 16-18) uses the terms strategic planning, management control, and operational control to designate roughly the same thing. Simon (1960, p. 49) also identifies three levels:

An organization can be pictured as a three-layer cake. In the bottom layer, we have the basic work processes... In the middle layer, we have the programmed decision-making processes, the processes that govern the day-to-day operation... In the top layer, we have the nonprogrammed decision-making processes, the processes that are required to design and redesign the entire system, to provide it with its basic goals and objectives, and to monitor its performance.

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This table draws extensively from Blumenthal (1969, p. 29).
inputs and disposition of the outputs have a major influence on the performance of the system.

8.1 Operational level. A discussion of data flow logically begins at the operational level because it is at this point that most data enter the system. An operational module may obtain its input data from transactions, from the data base, or from other modules. Figure 33 shows some of the input sources for an inventory control module. As can be seen from this example, data from other modules may come from either the operational or tactical level.

Outputs from an operational module often take the form of working documents. These are hard copy documents used to provide authority for action and to communicate with internal or external parties. Examples include checks, invoices (bills), material withdrawal authorizations, job move tickets, insurance policies, warehouse picking schedules, hospital laboratory reports, and student grade reports. In an on-line system certain outputs may be displayed in transient form, as in the case, for example, of a production control system in which a worker is informed of his next job by means of a CRT terminal located near his work station. Displayed output also includes reports used by tactical or even strategic decision makers.

A substantial proportion of the output may never be displayed. Instead, it is written in machine-readable form for subsequent input to a processing module. By this means one module can communicate with another (or with itself, for that matter, during a subsequent processing batch). For example, the order entry module can communicate with the inventory control module by generating a temporary file containing a set of internal messages that are read during the processing of the next module.
inventory control batch. Similar communications also take place in an on-line, real-time system, except that the intermodule messages may be handled one at a time. 14

Much of the output of a module is retained in the data base—as an updated Inventory record, for example. Such information is then available to any module—the accounting module, say—that has access to the updated record; this is shown in Figure 34. Communication among modules is, in fact, one of the principal advantages of their sharing a common data base.

8.2 Tactical level. A module at the tactical level has the same variety of inputs and outputs as found at the operational level. It may obtain machine-readable inputs from other modules and supply machine-readable outputs for other modules. It also obtains inputs from the data collection function and displays outputs for human use. See Figure 35.

Nevertheless, some important differences exist between operational and tactical modules. The volume of data is usually considerably less at the tactical level. Furthermore, inputs may require subtle adjustments, such as the determination of the standard cost of a raw material based on its past cost and any expected changes. Accordingly, many of the inputs do not come directly from another module; they come instead from a human source (who may rely heavily on reports displayed from other modules). Virtually all inputs from the strategic level enter tactical modules in this way.

Similarly, the outputs from a tactical module may feed directly into other modules; or they may require human intervention; the latter approach is more common. Even if the module automatically makes tactical decisions, the decisions are usually reviewed prior to execution at the operational level. In many cases a tactical module does not make decisions itself, but it merely provides selectively displayed information used by a human in his own informal decision process. In these cases the resulting decisions must be entered as input to some subsequent module. 15

It is usually advantageous to use by-product information from the operational level as the principal source of inputs for tactical decision making. In some cases, however, routine transaction data do not give all of the information required. Consider, for example, the case of forecasting. The current level of sales, as obtained from the order entry module, is obviously an important input for predicting future sales. But this only gives information about past sales; it does not take into account new factors that will affect sales in the future—things such as changes in the marketing strategy of the firm or its competitors, shifts in usage patterns of major customers, or economic trends. If these factors are to be considered formally by the forecasting

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14 The routing of messages among modules is somewhat analogous to letter sorting operations in a post office: each intermodule message must carry an "address" that identifies the receiving module.

15 In a formalized man-machine system, the final decision can be retained internally and fed to appropriate operational modules. This holds considerable promise, but it is rarely practiced today.
module, provision must be made for collecting cer-
tain environmental data that describe external ev-
teats outside of the immediate interest of routine operations. The data may be collected in the form of routine reports from salesmen, economic indicato-
glished by the government or sold by private eco-
nomic bureaus, or similar sources of "business in-
telligence" data.

8.3 Strategic level. Any of the differences be-
tween the operational and tactical levels are
magnified at the strategic level. Virtually no au-
tomatic decision making takes place at the strate-
gic level; the information system only supplies in-
formation to aid human decision making. A strate-
gic module may do little more than perform simple
summaries of tactical or operational data. A more
sophisticated system may allow the decision maker
to retrieve information selectively from the data
base through ad hoc inquiries. In still more ad-
vanced applications—where a so-called corporate
model is used, for example—a strategic module
may perform elaborate calculations to predict the
consequences of alternative strategic decisions
(and to determine the sensitivity of outcomes to
changes in controllable and uncontrollable vari-
able). In all of these cases, however, the human
creates alternatives and chooses among them; the
only design issue is which to the formal system
should aid the human decision maker.

Internal data generated from transactions prove
useful even at the strategic level. The operational
data base, when suitably summarized and selected,
often gives valuable information for high-level
management accounting reports, for example, rely heavily on such internal sources.

Nevertheless, Internal sources of information are
inherently limited in dealing with strategic is-
Sues. The current condition of the organization, as
reflected in the data base and recent transac-
tions, has little relevance for long-range decision
making. By its very nature strategic planning must
consider events and trends outside of the organiza-
tion itself. Little wonder, then, that the strategic
level looks to the environment for much of its in-
formation.

Some of the needs for external information can be
satisfied by the formal information system. Or-
ganizations are increasingly developing informa-
tion systems for the routine collection of economic,
competitive, technical, and demographic data.

Indeed, the sale of information of this sort has be-
come a sizable industry.
The system designer should not delude himself, how-
ever, into thinking that he can supply high-
level managers with all (or perhaps even most) of
the information they need. The decisions facing a
strategic manager, and the information required to
support him, are too unpredictable and unstructured
to permit anything like complete formalization. To
be sure, significant progress will continue toward
assisting strategic planners with such "routine" de-
cisions as choosing among alternate financing plans,
capital budgeting, and other strategic problems par-
циально expressible in quantitative terms. The re-
maining strategic decisions—including, no doubt,
some of the most important ones—must be left to
the human without any substantial aid from the
formal information system.

9. Integration of the Information System

A large information system consists of many
modules, sources of data, flows of information, and
processing resources. The activities within the sys-
tem may be tightly coordinated, or they may be a
loose assemblage of essentially independent func-
tions. An integrated system is one in which each part
is tightly linked and compatible with other
parts.

9.1 Characteristics of an integrated system.

There are four primary aspects to integration: (1) the
structure of modules; (2) the exchange of infor-
mation among modules; (3) the structure of the data
base; and (4) the sharing of processing resources.

Module Integration. A monolithic sys-
tem consisting of a single module can be viewed as
the extreme case of integration. All exchange of
information among subtasks would be handled inter-
ally within the module. Each subtask would con-
sider overall processing requirements and not join
its own independent portion.

Such systems do not exist. A task of any
complexity must always be broken down into rela-
tively small pieces. When dealing with the stag-
gering complexity of a large information system, the
module designer must break the problem down, aggregate
variables, ignore interrelations, and resort to simi-
lar techniques for simplifying the problem. The
only question is one of degree.

In as many of the issues connected with the
information system, the designer seeks a suitable compro-
mise between opposing effects. On
the one hand, the greater the fragmentation, the
simpler the individual pieces. But a penalty is
paid for this. Good designs for the fragments of an
overall system do not necessarily lead to a good
overall result. Suppose, for example, that the pro-
duction control module generates an optimum
schedule—in the sense that the schedule results in
the lowest possible manufacturing cost for a given
set of products to be manufactured. If, however,
the products so scheduled are not the ones that the
market demands, then the overall result may be en-
tirely unsatisfactory. What appears to be optimal
in terms of a narrowly defined objective (manu-
facturing cost) is only suboptimal with respect to
the firm's overall objectives.

In order to avoid serious penalties of sub-
optimization, it is important that the subobjectives
imposed on each module of a system conform reason-
able well with overall objectives. Conformity be-
comes more difficult to achieve as fragmentation
increases. In other words, as the number of mod-
ules grows and their scope shrinks, the relationship
between each module and the overall objectives
becomes more and more obscure. Consequently, the
penalties of suboptimization increase.

The designer seeks to balance the con-
lict between suboptimization and complexity. He
has simplicity through fragmentation, but he pays
for it in higher penalties of suboptimization. He
thus must give up one desirable effect in order to
get a greater benefit in striving for the best over-
all result. Figure 36 shows the sort of tradeoff that
the designer must consider.

A concrete example should help to clar-
ify this issue. Consider the case of an inventory
control module. It could be designed to include
both the physical aspects of inventory control (e.g.,
keeping track of the overall value of inventory)
These tasks are clearly related and use many of the
same inputs. If, so, the financial aspects were
handled in a separate accounting module, problems
of coordination and reconciliation are bound to a-
rise. On the other hand, a combined module would
be more complex. Its development would require
to skills seldom found in a single person. Furthermore,
responsibility for physical and financial control of
Inventory are normally lodged in separate organiza-
tional units; therefore, combining these functions is
apt to raise some serious jurisdictional problems.
Thus, the decision whether or not to combine physi-
cal and financial aspects of inventory control inevi-
tably requires a compromise between the complexity
of integration and the suboptimization of indepen-
dence.

The penalty of suboptimization stemming
from the separation of processing activities depends
greatly on the nature of the activities. If two activi-
ties interact closely with one another—requiring com-
munication, say, and mutually exchanging a large
amount of information—then separation may entail a
considerable penalty. Under these circumstances
the added complexity of a combined module may clearly
be justified. Thus, for example, we would normally
want to combine into a single module the processing
of all transactions that affect inventory balances,
such as receipts from suppliers, returns from custom-
ers, sales, scrap, and physical inventory adjustments.

If, on the other hand, two activities have
little or no relation to one another, the penalty of
separating them may be entirely insignificant. For
example, there would be no conceivable advantage
in combining the processing of stockholder transac-
tions (recording sales of shares, payment of dividends,
et al.) and inventory transactions.

Exchange of information among modules.

Fragmentation of the system could be 
used to exchange information among modules. For example, if
the physical and financial aspects of inventory con-
trol are handled by separate modules, the two mod-
ules are certain to exchange information. Since
fragmentation exists in every sys-
tem, the exchange of information among modules is
a universal requirement.

In an integrated system the transfer of in-
formation takes place through a machine-readable
medium. For example, the inventory control module
can supply intermodule messages to the accounting
module through a temporary file or a shared portion
of the data base. This transfer of information be-

See Section 8.1 above.
between modules comes at a cost. The sending and receiving modules must use mutually understood and acceptable coding, formats, and data definitions. The storage medium used in the exchange must be compatible across modules. The routing of a large volume of messages among multiple modules becomes a sizable data processing task in its own right. The sharing of a common segment of the data base raises some serious problems of security and priority.

The alternative to integration of information exchange is to permit each module to be responsible for the collection of its own inputs. Data may be collected entirely independently of other modules—when, for example, the marketing analysis system module obtains sales data from salesmen’s reports and the production control module obtains them from reports of actual shipments.

Data can also be exchanged between modules in a nonautomatic form. A printed record from one module can provide data that are manually prepared as input to another module. This eliminates the technical problems of obtaining machine-readable compatibility among modules; it also allows human review or adjustment of the inputs. For example, standard costs of purchased materials, which are used for planning and control purposes, usually do not come automatically from the operational module that processes purchase transactions; historical costs nearly always undergo human review and perhaps smoothing or normalization of some sort.

Just as in the case of module integration, the choice of the means for exchanging information among modules should consider the tradeoffs involved. Integration avoids redundant collection of data, with its attendant duplication of costs and errors. But integration also adds to the complexity of the system.

The added complexity is well worth the effort when dealing with large volumes of data. As the volume of information drops, however, the point is reached at which integration costs more than it saves. For example, it would rarely pay to design the plant maintenance module to feed information about machine breakdowns directly into the production scheduling module.

The subutility of the transformation of operational data into the form required by another module also strongly influences the degree of integration. The transformation is often particularly difficult when historical transaction data are used to generate future-directed planning data. Standard costs, allowed scrappage rates, labor and machine efficiencies, and the percentage returns from a given well-compensated example of plants and data that usually require human intervention to estimate from transaction data. Cases such as these normally do not permit complete integration of information exchange.

Very often the best compromise between integration and nonintegration results in a hybrid system. The exchange of high-volume inputs, or those that call for a straightforward transformation between modules (such as simple extraction or aggregation), can be integrated; low-volume exchanges, or those requiring complex transformation, can be handled by nonintegrated means. In the case of an inventory decision module, for example, sales of individual items can be obtained automatically from the order entry module. The unit cost of each item and the cost of machine setups, on the other hand, are almost always provided by a human analyst based on a periodic review of accounting reports.

Data base structure. If the data base were completely integrated, a given data element would be stored in only one place and then made available to any module that requires it. For example, information about a given employee could be maintained as a single record that provides inputs to modules dealing with such matters as payroll, salary and benefits administration, job selection, stockholder processing (for employees who also own stock), and customer billing (for employees who buy from the firm). A completely integrated data base would also allow any arbitrary association among records—linking all employees in a given department or those coming from a given university, say.

No data base is completely integrated. There are a number of reasons for this. Processing modules have widely varying needs for information and access the data base with widely varying volumes, frequencies, and response times (for example, the payroll module might access data once a week, while salary and benefits administration might call for on-line retrieval randomly throughout the week). Security requirements usually dictate that different portions of the data base be accessible to different authorized persons or modules. Furthermore, existing files, created over the course of many years by different organizational units, typically contain incompatible data elements (e.g., different data definitions, terminology, and product coding); therefore, even if the integration of the files were technically and organizationally feasible, the cost of conversion often severely limits the extent to which the files should be consolidated.

The data base is structured in a way that simplifies access and processing. Data elements that are usually processed together are stored contiguous (i.e., in the same tape record or in a nearby area of disk) in order to facilitate retrieval and increase efficiency of access. Conversely, weakly related elements are stored noncontiguously.

Segmentation of the data base into noncontiguous areas inevitably leads to some duplication of data elements. The same data element may be required as input by two different modules, but they may not have enough common inputs to justify the use of a common file; see Figure 37. The common data element must therefore be duplicated in separate files. Segmentation also inhibits associ-
Using Module

Representative Data Elements

Pay to date, vacation days to date, social security deductions to date, bond deductions, declared number of dependents.

Work history within firm, prior work history, educational history.

Name, address, employee number, current rate of pay.

Unique to Payroll Module

Data elements unique to Payroll Module

Pay to date, vacation days to date, social security deductions to date, bond deductions, declared number of dependents.

Unique to Personnel Module

Data elements unique to Personnel Module

Work history within firm, prior work history, educational history.

Common Data

Common data elements

Name, address, employee number, current rate of pay.

Figure 37. Data elements serving as inputs to two different processing modules.

Two different modules—in this case, payroll and personnel—usually have a different set of inputs, with perhaps some overlap. If the overlap is substantial, both sets of data elements may be consolidated into a common file (the "employee" file, say). If overlap is minor, it is usually efficient to duplicate the common elements within separate files. The alternative is to use a single, common file; this leads to the situation in which each module must access consolidated records that contain, for its own purposes, a sizable proportion of irrelevant data (e.g., the Payroll Module would have to access data about an employee's educational history.

Data across segments, thus reducing the degree of integration of the data base.

Again the issue of tradeoffs arises. A movement toward the totally integrated data base brings a number of advantages, but it also increases complexity and reduces access efficiency. Some integration of the data base is clearly desirable, but the designer must stop a long way short of complete integration.

Sharing of processing resources. The modules of an integrated system share processing resources. The most obvious candidate for sharing is the computer. Different programs may exist simultaneously in the computer's primary storage and share intermittently in processing cycles. A single multiprogrammed computer of this sort may serve a number of geographically dispersed facilities through data transmission links.

Computers generally exhibit substantial economies of scale—i.e., the cost per calculation goes down as the size of the computer grows up. Thus, by sharing a single computer, rather than maintaining one of his own, each user may enjoy the benefits of these lower costs. The load-leveling effect of having many users share a computer may also allow considerably higher utilization of its capacity. Similar economies apply to other processing resources such as communication network, data storage, and display.

These economies are offset to at least in part, by the effort required to allocate a shared resource. For example, the operating system of a multiprogrammed computer may consume perhaps 20 percent of the computer's processing cycles in order to handle the "overhead" associated with the allocation task. A dedicated minicomputer, specialized to handle a limited set of tasks, sometimes more than overcomes the last opportunity to gain economies of scale.

A shared resource increases the degree of interactions among the sharing modules. This can add greatly to the complexity of the system, with a resulting higher development cost and reduced reliability. Sharing very often raises serious political problems among those competing for capacity; if each executive prefers having his own secretary rather than using a secretarial pool, many managers prefer having their own processing resources that they alone control.

It is nevertheless true that most well-designed systems achieve considerable sharing. This becomes all the more true as advances in the computer's operating system increase the ease, reliability, and economy of shared use of the computer and other processing resources. Even so, the designer will often find it advantageous to dedicate resources to specialized tasks in order to gain simplicity, economy, and reliability.

9.2 Lateral and hierarchical integration. It is useful to draw a distinction between integration within a decision level and integration across levels. The former is termed lateral integration, and the latter is hierarchical integration. Figure 38 shows the difference between the two types.

Lateral integration occurs mostly at the operational level because it is here that massive volumes of data justify the effort in combining modules, exchanging data across modules, consolidating files, and sharing processing resources. The motivation for integration of this type is more efficient transaction processing—lower cost, faster, more accurate, etc. It is often achieved by combining tasks and sharing files or processing resources across existing organizational boundaries.

Hierarchical integration primarily concerns itself with the links between the operational level and tactical decision making to a limited extent. It is also concerned with links to the hierarchical level. The primary issue is the flow of summarized transaction data to decision processes, and the flow of decisions back to the operational level. The motivation for hierarchical integration is not simply processing efficiency; rather, it is to improve the relevance, timeliness, and accuracy of decision inputs and to improve the faithful execution of tactical decisions.

Although the motivations for lateral and hierarchical integration may be somewhat different, both forms must recognize the tradeoffs involved. Both forms add complexity to the system, and therefore must be justified by some offsetting benefit—lower cost of data collection, more accurate or timely data, greater reliability, or the availability of information that otherwise would be inaccessible to obtain.

Most of the attention paid to integration has focused on the lateral type. The issues and benefits of this form of integration are usually clearer than for hierarchical integration. Forging a link between transaction processing and managerial decision making calls for a variety of skills and raises some very difficult technical problems. It often proves advantageous to stop considerably short of tight integration and instead maintain relatively loose vertical links.

9.3 Effect of technological advances on integration. We have seen that four aspects of integration—the structure of processing modules, the exchange of data among modules, the structure of the data base, and the sharing of processing resources—all involve tradeoffs between the advantages and disadvantages of integration. The disadvantages largely stem from limitations in information processing technology. For example:

- Increasing the scope of a processing module increases the required size of the processor and adds to design complexity.
- Facilitating the exchange of information across module boundaries imposes additional burdens on the data base management function.
- Consolidating the data base and allowing rich associations among data elements complicates the data base management function and tends to increase the amount of data accessed by each processing module.
• Widespread sharing of a computer calls for large-scale computing power, sophisticated operating systems, and reliable and inexpensive communication links.

All of these inhibiting factors clearly depend on the current state of technology. As processors become larger, as access to files becomes faster and more efficient, and as operating systems and data base management software evolve, then the tradeoffs will tip in favor of greater integration. This phenomenon is clearly evident in today's systems. Complete integration, as far as we can foresee, will always remain technically and economically infeasible, but the trend is certainly toward a greater degree of integration.

10. Are We Talking About a Management Information System?

Up to this point I have been careful to avoid the term management information system (MIS). The term has been given so many different meanings that its use is subject to a great deal of confusion. Some of the more popular meanings are:

• The complete information processing system — i.e., the strategic, tactical, and operational levels.

• The decision-making components of the information system — i.e., the tactical and strategic levels.

• The tactical and strategic levels but not including formalized decision models.

• Any existing data processing system, which is usually confined mostly to routine transaction processing.

• A colossal myth fostered by computer salesmen, consultants, and professors.

Despite the misunderstanding and disrepute into which the term MIS has fallen, it is, in my opinion, still worth retaining. It is widely used, and so any replacement term would have to overcome the common (if grudging) acceptance of the term. Furthermore, any replacement would no doubt encounter similar difficulty in gaining a clear and generally accepted meaning.

It seems useful to use the term MIS to describe the overall formal information system of an organization. In particular, the MIS includes both the transaction processing portion as well as the decision-making portion; it also includes formalized decision models. Any attempt to exclude certain information processing activities is bound to be arbitrary and misleading.

We can thus summarize the characteristics that give MIS its special qualities:

• An MIS deals with the task of running an organization.

• An MIS is heavily dependent on a large and interrelated data base, and thus imposes severe requirements on the data base management function.

• A well-designed MIS will always rely to some extent on computers and related technology (except for the very small organization). Computer processing has become too expensive and universally available in technologically advanced nations that failure to use it constitutes prima-facie evidence that the MIS does not provide a suitable balance between the cost and value of information.

• A well-designed MIS relies heavily on human decision making. It is neither technically nor economically feasible to formalize completely all of the unstructured problems encountered in managing an organization. Human decision makers receive varying degrees of assistance from the MIS; the nature of the aid can range from relatively trivial rearranging, extracting, or summarizing of information, to a closer partnership in which the computer significantly extends the problem-solving capabilities of the man.

• A well-designed MIS reflects a compromise between formality and informality, integration and fragmentation, high quality information and uncertainty. As technology advances, the tradeoffs favor greater formality, integration, and information quality.

• The development of an advanced MIS for a large organization is among the most complex tasks routinely attempted by man. It can consume millions of dollars of resources.
and requires for success high calibre training, experience, and intelligence.

Although these characteristics are quite broad, they exclude some important information systems. For example, scientific or engineering programs cannot be considered an MIS. A process control application—controlling a petroleum refinery, say—is likewise not in itself an MIS.

Whether or not it is useful to consider applications of this sort as part of the MIS depends on the circumstances. Consider, for example, a program that assists an engineer in designing custom-made equipment for specific customer orders. A completed design is fed (perhaps automatically) to the production scheduling module. Such a design program should probably be included as part of the MIS. So, too, should a process control module that receives its set points (i.e., the operating conditions) it is instructed to maintain from a higher level planning module and provides summarized sensory data about plant operations to other modules.

Attention to the scope of the MIS is not an academic exercise; it has important organizational implications. It matters a great deal that the design of the MIS consider the relationships between decision making, transaction processing, and engineering-type calculations. Design decisions must be made concerning the consolidation of processing modules and data base records; exchange of information among modules; and the sharing of hardware, software, and files. Realistic tradeoff studies that consider the high risk and cost of developing a tightly integrated MIS will often conclude that decision making, transaction processing, and engineering calculations should be only loosely coupled. Once the interfaces among these components have been agreed upon, each can be developed more or less independently. But unless an overall view is taken of the MIS (as it has been defined here), the possibilities will largely be lost for exploiting whatever opportunities exist for well-founded integration.

Having discussed at some length the most important characteristics of an MIS, it is appropriate at this point to summarize the discussion in the form of a succinct definition of an MIS. A management information system is a set of formalized procedures for collecting, transmitting, storing, retrieving, and transforming information for the purpose of aiding humans to operate an organization and direct its behavior toward desired goals.

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