MANAGEMENT UTILIZATION OF DATA PROCESSING SYSTEMS FOR FIELD CONTROL

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•THE TOPIC issued for this discussion, "Management Utilization of Data Processing Systems for Field Control," is one of great interest to me, and, I feel, of substantial interest to most persons involved in the development of management systems of the kind and type that are the subject of this Workshop. I would like to approach this discussion by selecting what I consider to be the major disappointments that have occurred in using data processing systems for management, and by offering some suggestions for overcoming these nonsuccesses.

RESULTS OF USING DATA PROCESSING FOR MANAGEMENT SYSTEMS

The experience to date in the use of data processing systems for management information, regardless of whether these systems have been involved with a field operation or an industrial operation with a compact area of interest and controlled environment, has been somewhat the same. The systems have generally been used with a mixture of success and disappointment. The successes have generally been related to the increased ability to consolidate and statistically manipulate data. In too many instances, the successes have been overshadowed by disappointments of goals not achieved. The disappointments, in general, fall into three categories:

1. The use of data processing did not of itself bring better management to the operation; i.e., costs were not reduced because reports were generated by a computer. This disappointment has occurred when the relationship of the role of data processing to management was misunderstood;
2. The use of data processing in place of manual methods has often been less timely, and, at least apparently, has often produced results that have been less accurate; and
3. The use of data processing has not always provided useful management information for particular problems, or for particular inquiries which are unusual in nature.

Each of you can probably cite other problems than these which you have personally recognized, but these are considered to occur most generally and to be most critically in need of solution. The balance of this discussion will be directed to these problems and to the approaches which hold promise for their solution.

RESTATEMENT OF THE ROLE OF DATA PROCESSING SYSTEMS TO MANAGEMENT

I have selected this issue because, unless there is a clear idea of the objectives of both the data processing system and the management system which it supports, it will not be possible to develop such a system properly, nor when it is finished will it be possible to determine whether it is a success or a failure. At first consideration, this issue would seem too obvious and basic for discussion. However, experience in system development has shown that it is these basic concepts which are more often misconstrued or forgotten than the detailed concepts.

Although this is not a lecture on management, I feel that it is important to restate some obvious facets of management by asking and answering some questions.

1. What are the components of a system for managing field operations? The term "system" does not refer only to a data processing system, but to the total makeup of people and operations that is required to manage the field operation. These major components are: (a) a well-structured, well-trained, workable personnel organization; (b) standardized work procedures with accomplishment units expressed in quantified form, all documented for understanding; (c) the method of processing and converting data related to the operation into quantified usable information; (d) a method for bidirectional communication of information and management directives, in terms of quantified accomplishment and financial units, between the field and the appropriate decision-making levels; and (e) a management decision-making function at each proper level and location of responsibility.

2. Which of these component roles can a data processing system fill? It is very obvious that a data processing system cannot fill the role of a personnel organization or of the documented work procedures. Although it is not so obvious, a data processing system should not be given a role which can be considered decision-making. Computers can be programmed to make decisions that can be reached by a preprogrammed analysis of data. In fact, if the data are very complex or if the decision must be reached at very high speeds, computers are more capable than humans at this limited condition of decision-making. Management of operations, however, requires a different form of decision-making. Seldom can the decision be reached solely on the basis of data without the use of experience and judgment. Decision-making then is essentially the problem of the manager.

The data processing system can, however, if properly programmed, process large volumes of data efficiently into information. This information may contain the results of many rudimentary data-based determinations which fall below the level of bona fide management decisions. If the data processing programs are very sophisticated, they may even produce what amounts to management recommendations, in certain constrained areas. The true decisions, however, should be made by the manager.

3. If the data processing system does not produce decisions, and if a manager, in order to have a good enough feel to make decisions, must have personal contact with troublesome problems, of what use is a data processing system? The answer to that is that the information produced should highlight areas that need personal attention, establish trends, show the limitations within which the manager can take decisive action, and be the media for quantitative communication. That is the extent of the role of data processing information systems.

As a positive step to achieve this proper relationship of data processing to management, I suggest that the relationships and objectives be clearly and repetitively expressed and that management keep a watchful eye ready for persons who are still confused at these relationships.

THE PROBLEMS OF TIMELINESS AND ACCURACY OF DATA PROCESSING SYSTEMS IN PRODUCING MANAGEMENT INFORMATION

The lack of acceptable timeliness and accuracy can be caused by an improper computer configuration or by computer programs that have been poorly designed or tested. Experience has shown, however, that in the majority of instances the problems of dissatisfying timeliness and accuracy have been due to the lack of dedication to the manual procedures required to accompany the computer operation, rather than being the direct fault of the computer operation itself. Since this problem of computer selection and program checkout is more suited to a computer conference than one of this nature, I will hold the discussion to those problems related to the processing steps leading up to and out of the computer processing itself.

Before the employment of computers, we used less data to arrive at our information because we could not manually process more. The manual procedures, over the years, were gradually built up, along with the staff of personnel necessary to complete the process within the time requirements. With the institution of computers, we have accepted more data than we allowed in the manual system because the computer was capable of handling it. We have not always, however, designed the procedures nor sup-

plied the people required to handle this information without creating bottlenecks before and/or after the computer process.

In order to understand more clearly the scope of the data processing procedures that accompany the computer operation, I would like to list them as specific steps. The following list assumes that data processing begins when data are first reported in the field and includes all intermediate steps until these data have been converted into useful information that resides in the appropriate place for management needs. It includes also the use of data processing in transmitting management directives back to the field. These standard data processing steps are:

1. Data capturing—the recording of data in permanent and reusable form (example—field recording of work accomplishments);
2. Data collection—the gathering of individual data items into processible groups (example—the collection of accomplishment records at a district office);
3. Data conversion—the transfer of data from human-readable into computer-readable form (example—keypunching of data forms into punch cards);
4. Data purification—the correction and improvement of data incorrectly recorded or converted, or the regeneration of lost data;
5. Data transmission—the sending of data to a computer site for processing. This step may be separate or a part of the data collection operation (example—the use of mail or telephone lines);
6. Processing of data into information—the computer organization of the data to provide the desired information; and
7. Information display and transmission—the presentation of information in human-readable form such as reports, and the sending of this information to its proper location (example—mailing of computer printouts).

The makeup of the maintenance and data processing organizations have a major effect on the procedures that are selected for each of the data processing steps. The maintenance organization that does not have field crews reporting each day to a somewhat central maintenance site that has an office facility with clerks requires that the crew itself be the unit that captures the source data. This, in turn, can imply the method of data recording, based on the confidence level in the field-crew skills and/or the excessive cost of supplying recording equipment to the many individual crews.

All of the data processing steps are interrelated, so that a method selected for one step may determine the method employed in another step. The goals of accuracy and timeliness are also interrelated since a good method to achieve one goal in a particular step may require a particular method in another step that will be counterproductive for one or the other goal. As an example, a field-data-capturing step that requires a paper document for best accuracy of recording will also dictate that the transmission method be physical transportation, such as by mail or hand carrying. The method of recording to achieve accuracy therefore dictates that the transmission method be one that is not as timely as the transmission of digital information over telephone lines.

There are several methods of data processing that may be used for each step, with innumerable ways of combining them to fit the requirements of various organizations. Instead of attempting to describe the significance of all possible combinations, I would like to describe the data processing methods of a theoretical operation as an illustration of one of the most difficult situations for the achievement of accuracy and timeliness of processing. This example presumes an organization of field crews operating out of individual crew sites. The field crews have no clerical assistance except that available at remote district offices, where various administrative functions such as payroll preparation are performed for the entire district. All computer functions are performed at a central site, which is separate from the district clerical function.

1. Data capturing—The field crew manually fills out paper-type forms with all pertinent maintenance management field source data. The same data are used for other administrative purposes, such as payroll computation. This type of data-capturing technique has the advantage in that it places the recording of source data right at the work location, develops a good document for auditing purposes, and combines the in-

put procedures of the maintenance system with the input procedures for other systems, such as payroll. It has the disadvantage, however, that field personnel, in general, are not well suited to this type of work in either skill or interest. Because of these disadvantages, the accuracy of the data-capturing operation often suffers.

2. Data collection—Source data forms are collected by the maintenance supervisor and either are hand carried to the district office, or are mailed directly to the district office by the field crew. Because the data are held on paper-type forms, they must be physically transmitted rather than by utilizing the higher speed of telephone line transmission, as could be done if the data could be converted to digital form. In addition, since the information is on physical units of paper, it must be put into meaningful batches at the district offices for processing, which, in this case, means sorting, grouping, totalling, etc., to control the documents and prevent loss. The transmission method of mailing or hand carrying is obviously slow, and the manual handling procedures are very time consuming. Because the paper procedure requires significant handling and the clerks doing the work are removed from the data recording process, there is also substantial room for mishandling of either the documents or the data contained thereon. Although definite attempts are made at checking the data at the district site, the volume of data and the interrelationship of data items between different documents make this procedure one that is of only partial value, when compared to checking by computer. Many of the handling procedures of this step are much more suitable to computer operations than to manual operations, in order to achieve accuracy and timeliness. The problem, however, is that the data and the computer are not at the same physical place so that the computer cannot provide its assistance.

3. Data transmission—The batched documents are now sent to the computer center by mail for conversion and computer processing. It hardly needs to be stated that the mailing process today is a slow and danger-fraught experience.

4. Data conversion—All data conversion capabilities are located at the central computer center, separate from either the district offices or any maintenance facility. All of the batches of source documents from all district offices are gathered at specific periods during the month and keypunched into cards, with substantial amounts of accompanying paper control procedures being required. Normally, collection and conversion occur twice a month. The data conversion operation is another operation prone to loss of accuracy. Key verification procedures provide reasonable checks for assuring reliable transfer of data from a document to a punched card, if the data are recorded with high quality. It provides no assistance, however, for interpreting questionable data on the forms. Neither will it help cross-correlate various items of data from one position on a card to another, nor will it correlate data between cards. The conversion of large batches of data at one time can be accomplished relatively speedily if proper staffing, planning, and a well-organized gang approach all take place. No matter what batch approach is taken, it can never be accomplished as quickly as when each day's data are converted daily.

5. Data purification—When all data are converted into machine-readable form, the machine-readable data are again batched with appropriate manual handling control procedures and processed through a computer. The purpose of this process is to analyze the data contained thereon, not only on a single card field or on one card, but on all related fields of all cards of all related groups. Reports are produced which show all discrepancies within the data. These reports may be analyzed and the data corrected in the central location, or the reports may be mailed back to the district office for purification. If the reports are held and the data are corrected centrally, much telephone calling and questioning is required to determine how the data should be corrected, all with accompanying lost time. If the reports are mailed back and forth to the district offices, the lost time is also significant. In either case, the time required for purifying the data is seldom less than 7 to 8 days. The degree of accuracy realized is solely dependent on the dedication of a clerking staff, which has little direct knowledge or interest in the field operation itself, and on the amount of pressure that is placed on the completion of the data purification job so that the system reports can be generated. If the pressure gets too great because too much time is passing, the degree of purification goes down.

6. Information display and transmission—Upon obtaining acceptably pure data, the computer processes the data and generates the preprogrammed reports. The reports are reviewed at the central location to assure that the process has gone on satisfactorily, and are then generally hand carried and/or mailed to the appropriate management level. Again, the transmission technique is that of slow mail. The prereview of the output before mailing is, again, by persons who are not familiar with the maintenance operation, and who must, in a slow process, go through a large amount of output before they can release the information.

Throughout the preceding dissertation, we have noted that unsatisfactory accuracy and time delays occur at a number of steps in the process because we required manual processing to do voluminous detailed work that was more suited to computer processing, and several mail transmissions of physical documents rather than the faster phone-line transmission of digital data. We were forced into this situation because we did not have good procedures to place the data in the appropriate location in relation to the computer, nor did we provide other modern data processing techniques at the disposal of the field or district personnel.

I would like now to describe an alternate approach to the above system that I believe would significantly improve it in both timeliness and accuracy. Other alternatives could be substituted, but care should be taken to see that all techniques used will work toward the same goal and not in opposition to each other.

Without organizational changes or locational consolidation of the just-described ineffective operation, some of the following suggestions for the alternate approach will be neither practical nor economical. Even if the organizational and locational changes take place, it may be required that other systems be redesigned to utilize the same equipment, techniques, and data files in order to justify economically the required investment in new equipment. With this set of qualifications, let us begin the discussion of the alternate operation.

I would like to make as the first suggestion that locational consolidation of the theoretical maintenance organization take place so that as many crews as possible would report daily to central maintenance site. At this site would be an experienced clerk, familiar with the local area being maintained and the existing work schedule of the field crews. This one change alone would provide the entire system with competent clerk-type personnel having understanding and ability to handle the majority of the data-capturing, conversion, and purification steps with confidence and with direct access to crew leaders for answers to questions concerning the source data. This suggestion may be presumptuous because it smacks of data processing procedures causing the reorganization of maintenance; the classical tail wagging the dog. However, I intuitively feel that with the additional benefits to be gained from this move and the benefits realized from other operations, such as storehousing, that it may be justified.

The primary objective of this first recommendation is to place, in a timely manner, the data-capturing procedure in the hands of a clerk who is trained to the needs of this technique. By concentrating the data-capturing requirements of a fairly good size number of crews at one location, there could be adequate justification for placing data conversion at the same location. If data conversion could be placed at this maintenance location, we could then take advantage of electronic data transmission techniques to eliminate the slower, less reliable mail and hand-carrying methods. If we can make use of electronic transmission, we also can use this media to provide reports back to the maintenance site, a procedure which would allow the maintenance clerk to perform the data-purification steps. Should it not be feasible that data be converted to digital form at this location, the next most desirable step would be to have the data-capturing technique performed at the maintenance site in such a manner that the data conversion could be an automatic process at the central computer location, thus at least providing improved speed and accuracy for data conversion. The following is a list of steps that would conform to the preceding suggestions:

1. The maintenance-site clerk would record the maintenance system source data from each crew at the end of each day. He would record it on log sheets, so that there would be a permanent record that could be used for data conversion and then filed.

2. At a set time the next morning, the clerk would use a simple on-line keyboard terminal such as a typewriter, teletype, or cathode ray tube with keyboard, to encode the data records from the previous day's work. He would key the information directly into the terminal.

3. The data would then be transmitted over the telephone lines directly into the remote central computer. The data processing group would set up the computer with the appropriate maintenance management system input program so that all maintenance sites would be able to perform their data-conversion operations in a time-shared mode during a fixed period of time each morning.

4. Input data messages (i.e., data that have been punched off the reports of the previous day's work) are received by the central computer and analyzed by a validation program in the computer, and error or acceptance messages are returned to each maintenance site. The computer would report as to whether or not the information the clerk had keyed in was acceptable to the system, and the clerk would take the appropriate steps to develop acceptable data.

5. Upon completion of the process, all data input would be clean, except for a few entries that would require checking with the specific crew leaders that night. All clean input for that day would be stored centrally in a data file for processing of management reports.

6. Data files that had been created could be used by the district offices or the central office for the development of payroll or other administrative requirements. All data would have been purified and ready for use on a one-day delayed basis.

7. Each day's transactions would be recorded on the typewriter at the maintenance site so that the clerk would have a complete record of all work that had been completed and had been entered as input to the system.

8. The maintenance management system reports would be produced at the appropriate period during the month, as soon as the data processing group assigned time to run the reports on the computer. No longer would it be necessary to wait for a particular cutoff period before beginning the time-consuming data-conversion, data-transmission, and data-handling steps that are currently a prerequisite before these data are available and reports can be produced.

There are other options and combinations of techniques that can be substituted in the just-described operation. In fact, there are too many to be elaborately discussed in the time allotted. I would like to comment on a few of the other useful techniques just so that they may be related to the described operation and so they can be related to the special needs of particular organizations.

1. Optical character reading—This technique uses paper documents with printed characters that can be machine read in order to produce computer-readable data. It attacks the data-conversion problems for both timeliness and accuracy. It requires that the source data be placed on the document either by a typewriter or by a plastic embossed card imprinter, similar to a credit card imprinter.

Optical character readers are normally expensive enough that they must be placed centrally, in the same manner as is a computer. Remote scanners of more reasonable price are becoming available, but it appears that their cost and current stage of development will preclude their use for some while yet for most organizations.

Optical character reading is a desirable technique if the data are not converted through a keyboard-like terminal at the remote site, as previously described. It has the less-than-desirable feature that transmission to the central reader, just as in the first operation described, is still by mail because the documents are still physical documents. It also has the same purification steps and problems that were described in our first operation, in that the purification must take place remote from the location where the greatest understanding of the information resides.

2. Data conversion to computer-readable form at remote locations—Data can be placed on a computer-readable medium such as punch cards and paper or magnetic tape at the maintenance site just so long as the device prints hard copy for clerk interpretation. Unless, however, there is a data reader at that particular location, the information cannot be transmitted over phone lines, but must be mailed to the central location

with all of the resultant problems previously discussed. If a data reader can be placed at the maintenance site, then the procedure that is discussed for on-line data preparation is about the same as this operation, except that most data readers are more expensive than on-line terminals.

3. Data recorded on mark-sense cards—Field crews can record data directly on punch cards by mark-sense techniques. This is a useful technique that has, however, several problems. It is directed primarily to the solution of the problem of data conversion. There is a limited amount of data that can be recorded on a single card without a rather comprehensive set of correlation codes being used to compact these data into the allowable card columns. The recording technique is generally not familiar to field crews and, because of this, is somewhat prone to error. Mark sensing only aids the problems related to data conversion. It can, in fact, hinder the data purification task by making it more difficult for anyone except the originator of the document to interpret the intent, since its characters are merely black marks placed on a card.

There are other devices that can be used by a field crew or a clerk at a maintenance site to alleviate one or the other of the problems cited. However, none of the approaches attacks so many of the problems which exist as does the maintenance site's use of keyboard input directly into a central computer.

THE PROBLEM OF PROVIDING MORE SATISFACTORY INFORMATION TO MANAGEMENT

The third problem to be covered in this discussion of uses of data processing systems for management information is that we often do not produce the right information for the particular manager and problem. In many instances in the past, data processing systems have been developed under the misconception that the systems were producing useful management information. This assumption was predicated on the fact that the systems were able to convert large amounts of data into consolidated reports of various types and forms. This assumption was not erroneous so long as we knew for sure that the final reports would contain really useful information for the problems at hand, so that the information was neither too detailed nor too concise, and so that it was the type of information suitable to the particular manager to whom it was presented. It is the latter set of "ifs" that could seldom be met by the computer equipment of the past and by the system-design philosophy that resulted from this equipment. This design philosophy was essentially, "Tell me what your input is, what you want in your management reports, and we will design the system." The trouble with this philosophy is that seldom is a system designer, or for that matter a manager, able to know in advance what specific information, or degree of detail, he would need for each of the very wide range of problems that confront management. The predesigned reports emanating from the computer system generally were useful for the standard review of such things as the existing status of the project, but seldom were they useful when the manager wanted to know the "why" of a situation by breaking the totals down into their time-related components. Once the data were converted into data-processing form, they became lost for anything other than the predesigned report forms.

As we are all well aware, managing of a field operation is one of the more difficult forms of management because such operations are generally widely dispersed and there is very little direct contact between the manager and the operational problems themselves. The manager, therefore, when he is making his decisions, would like to have the widest possible range of information available to overcome the lack of problem-feel. Much of this information is grounded on data, although some is not. Following are some of the classical information needs of management that are based on data:

1. Information descriptive of the current existing field conditions.
2. Historical information on which projections can be made of probable future requirements to achieve desired objectives.
3. Information from current time into the future, concerning availability of resources of manpower, dollars, etc.
4. Information on which to evaluate the efficiency of the operation for purposes of improvement.

5. Information to provide responses to inquiries of the general public related to field operations.

Of all three of the problems covered in this discussion, I feel that this latter one may be closest to the hearts of the managers. It relates directly to a manager's ability to get a better look at all sides of the information pertinent to the problem, which hopefully will have a direct bearing on the quality of his decisions.

As indicated previously, data processing systems for management have historically been designed as fixed reporting systems with the reports being established of necessity in advance of the development of the system. The resulting reports were generally better suited for determining status at a particular moment but seldom for providing the reasons why.

This concept of data-processing-system design evolved because computers, in their early stage of development, had neither the access to adequate memory capacity to store large files of data nor the computational power to handle the large files and organize them efficiently and quickly upon request. The available program techniques were not suited to data handling nor to having an information-request flexibility which would handle random requests. Although I cannot say that all of the software problems and procedures for this type of concept are completely solved today, I feel that there has been adequate development to warrant consideration of using this concept.

The concept that I suggest is that of building system "data bases" which can be accessed by general data management programs. A data base is a large organized file of formatted data records of various types having defined contents in all fields of the records. It is not a "data bank" which conceptually stores data that may or may not be needed in the future. The data base contains only data that have been planned for and for which use is known. However, it has the capability of having new kinds of data added to it after it has once been developed and built. Data are retained in the most detailed unit for which they are designed until a request calls for a particular consolidation of the data. A history of data consolidations may become part of the data base itself for future manipulation.

The key to the use of the data base is the general data management programs. These programs, of which several very general and competent ones are available today, will do all of the file housekeeping, the data arrangement for a specific request, and the report generation. The information requester constructs a command set describing the data he wants, and the way in which he wants the data handled to create the desired information. These requests are normally English language in form and allow requests for statistical manipulation as well as summarization techniques. The resulting reports cover only the scope and the detail of data that are requested by management. The report makeup is then in the hands of management rather than under the control of a systems man. The manager can then request several arrangements of information until he has an arrangement that is useful to him. These request capabilities will help to eliminate the problem which exists when all manual records are turned over to a data processing operation. There is generally no way in which to get answers to special inquiries.

Many data processing pictures now show a manager facing a cathode ray scope and keyboard, keying in his own information requests. This may come to pass, but I rather suspect that we should begin by having the manager forming his requests in his own words to a management systems supervisor who will "converse" with the data processing system.

At any rate, this concept should provide managers with all of the information they want, in the way in which they want it, when they want it—if the information can be obtained from data.

CONCLUSIONS

I am personally quite enthusiastic about the possibilities of the latter two concepts discussed in this paper in overcoming the major problems involved in allowing data processing to live up to its potential for management information systems. We have worked for some years with systems that have had weak links that I feel are about to

be strengthened. I will not be so optimistic as to feel that if these concepts are successful some other link will not show up as a weak one. However, I feel that many of the managers who have had the greatest disappointments in data processing systems of the past can now begin to have these disappointments overcome.

With regard to my discussion of the relationship of data processing to management I would like to reiterate that we should be wary of the data processing man or the manager who expects that a data processing system should manage. Until we all recognize that data processing systems provide information, and managers manage, we cannot expect to achieve our management goals.

In closing, I would like to repeat a quote concerning the development of management information systems that is worthy of a paper in itself: management information systems should be "not built, but grown; not delivered, but infused."