A STUDY OF COMPUTER SYSTEM HARDWARE REQUIREMENTS FOR THE PURPOSE OF PROJECT CONTROL IN A GENERAL CONTRACTING CONSTRUCTION FIRM

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ABSTRACT

A STUDY OF COMPUTER SYSTEM HARDWARE REQUIREMENTS
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This report addresses itself to the requirements of a general contracting firm in performing the function of project control. In particular, with respect to the implementation of an in house computer management information system, this report investigates the type and quantity of data that would be input and output and the users who would utilize the system. The benefits of a computer management information system are also discussed.

This report also addresses itself to those features and requirements which are to be considered when deciding what computer equipment should be selected and how the system should be configured. It also displays the type of calculation that is involved in determining the capacities of the computer hardware system components required to fulfill the requirements of the firm.

PREFACE

A Study of Computer System Hardware Requirements for the Purpose of Project Control in a General Contracting Firm.

The information presented in this report was gathered by means of a literature survey and from interviews the author conducted with representatives from general contracting and engineering companies. The author also drew on his varied personal experiences in working with computers and in construction and real estate activities. The author's computer experience includes working with mainframe installations, small business systems and microcomputers over seven years. His experience in real estate and construction activities spans five years.

This Major Technical Report was written to be easily understood by the reader with a very limited background in the computer field. With this aim in mind certain efficiencies were sacrificed to the goals of clarity and ease of reading. For example, although a glossary of computer terms is provided following the text, definitions are also provided within the text wherever deemed expedient.

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Chapter 1

COMPUTER BASED INFORMATION SYSTEMS IN THE CONSTRUCTION INDUSTRY

1.1 Introduction

In the construction industry changes and trends are occurring which are making computer based information systems more applicable to medium and smaller sized general contracting firms.

These trends apply to both the construction industry and to the computer industry.

Project size for a construction firm is often in terms of millions of dollars. The scope and risk exposure of such ventures demand close and accurate project control. This close, accurate project control often requires large amounts of information to be compiled and reports to be produced in short intervals of time for use by management.

The ability of computer-based systems to handle large volumes of information, to process it, compile it and produce reports accurately and very quickly as compared to manual systems, as well as the fact that costs for hardware and software with regards to computer processing power are continually decreasing make the computer-based information

systems a prime consideration for construction firms.

When a computer-based information system is installed, a formalized system is set up to ensure proper data entry processing and output. Formalized systems tend to ensure that management gets the information that is desired and required and that it is complete and on time. At the same time they help minimize management involvement in report preparation. This project control information includes job costs, change orders, equipment rentals, work scheduling, resource allocation, reports, audit trails etc. Formalized systems also tend to reduce the impact on the project of change of personnel and so can tend to increase the flexibility of project managers and other company personnel. It should be realized that in any firm which has been operating successfully for a number of years systems of information processing are in force although very often informally. In this case change of key personnel can be quite traumatic to the firm.

When implementing formalized systems care must be taken to ensure that listed procedures do not replace the thought process. Each project has a portion of

individual character and this must be allowed for; i.e.--built into the formal system.

The implementation of a new system can sometimes effect a change in the procedure itself. The introduction of a computerized management information system can result in changes in the methods of project control. The investigation of this is beyond the scope of this report. This report considers only the implementation of a computerized management information system to the existing procedures of project control.

There are many factors that must be considered before a company can decide to make use of a computerized M I S (management information system). As outlined above the increasing capability of a computerized M I S to process large amounts of data quickly, accurately and economically lends itself nicely to the requirements of project control.

In addition, besides the technically related considerations there can be significant changes in the management and information flow structures of the company. These changes can be traumatic for the existing company personnel and their significance should not be underestimated.

Any M I S system must also be considered within

the context of the operation of the company. In addition to project control, firms must perform basic accounting functions including accounts payable, accounts receivable, payroll, general ledger etc. The M I S employed by the company can be comprehensive and integrated, i.e.--one system to perform all of these functions including project control, or it can be discretized whereby a different M I S would be utilized for each of the above functions, or some combination of the above functions. (A comparison of the relative merits of integrated or descretized systems requires the examination of the accounting and other functions performed by the firm and so is beyond the scope of this report. However an integrated system is implicitly assumed.) In addition, the M I S can be centralized or decentralized in nature, storing and processing data in one large data bank or in several smaller ones.

Consideration of system types would include:

--manual

--in house computer

--computer service bureau

--a combination of the above.

These system types would each be considered with regards to most or all of the above mentioned factors.

1.2 Objectives Of The Major Technical Report

It is the objective of this Major Technical Report to examine only one of the above system types, that is the acquisition of an in house computer in particular with respect to the hardware requirements as related to project control.

The requirements of a construction firm will be examined. Based on these requirements and on equipment currently available on the market, a satisfactory computer system will be formulated.

This report will not constitute a recommendation to acquire the formulated system since before acquiring any system all system types should be given the same detailed consideration, and the other system types will not be considered in this report.

Specifically the objectives of this Major Technical Report are to:

1) examine the process of project control as exercised by a general contractor in the construction industry.

2) identify and examine the information requirements and isolate problems for which a computer based Management Information System would provide at least a partial solution.

3) describe the fundamental building blocks of computer hardware required to construct a system with respect to objectives 1) and 2) above.

4) design a conceptual computer system considering only the hardware performance of the components which will meet the company's requirements and will take into account the type of computer hardware currently available on the market.

The computer system arrived at will be based on the fulfillment of company requirements. This report will not recommend or compare actual available computer systems.

Due to the limitation of scope of this Major Technical Report, some important issues will not be discussed. This report will not address itself to the requirements of other systems such as accounts payable, accounts receivable, general ledger, payroll, etc., except as related to the transfer of data to the project control systems. It will also not address itself to the possible personnel problems or restructuring of the company which may be necessitated by the implementation of such a system.

1.3 Advantages of the In House Computer System

As compared to manual systems, the main benefit provided by the computer is the speed with which it can accurately process information, compile it, and assemble it into reports. In addition because of its

great speed, completeness and accuracy when processing data, it can be used to provide a much greater variety of reports and accountings than can the manual methods. The aim of producing these various reports quickly is to provide management with the tools to assess the situation and provide timely decisions or actions to correct deviations from the desired directions.

The Computer Service Bureau is an establishment which is in the business of providing the service of processing a client's data by means of a computer. This service usually consists of picking up the client's data which is on forms or cards and delivering the results a specified time after (i.e.--next day, after two days, etc.) Sometimes arrangements are made such that the client (contractor in this case) has a terminal and printer in his own office. These are connected to the computer at the service bureau. The data is typed in the client's office using the terminal and transmitted to and stored in the office of the service bureau. It is processed at a later time and transmitted back to the printer in the client's office where the output data is printed out.

When a company has an in house computer system, they own or sometimes lease the hardware and the standard available software. They are responsible, however, to produce, update, and maintain their own custom software and to maintain the hardware. If the computer system is owned

by the company the hardware may be maintained by giving out a service contract, while if the computer is leased the servicing of the hardware may be contained in the lease.

When a company has an in house computer system, they also have control of what work it will do and at what time, and also of the procedures followed to process and distribute the data output. The fact that computer job control and turn around time are under more direct control results in the computer system being more flexible with respect to the company's needs and the data output being available more quickly. If a service bureau gets too busy their turnaround time could become longer. This could result in problems for the companies using this bureau. In addition, if the service bureau fails and goes out of business this could result in traumatic problems for its clients since most of them will not be equipped to easily handle their own data processing.

An additional feature of having an in house computer system is that software can be customized to provide services that are not otherwise available. Customized software may be designed by in house trained staff or subcontracted out to software houses.

An additional benefit of having an in house computer system is that greater security measures may be installed to protect sensitive data from unauthorized usage. When using a computer service bureau the client is dependent on the bureau to utilize adequate measures which it may or may not do.

1.4 Disadvantages of the In House Computer System

Due to economic considerations the company deciding on an in house computer system will usually have a smaller, less powerful, slower system than that of the computer service bureau whose equipment cost is in effect shared by many users. The in house computer system will usually be more difficult or expensive for the company to update as new machine advances come out and existing hardware becomes obsolete. As the hardware becomes obsolete it tends to become more difficult to maintain and service. This is true even for standard items but is especially true for customized items, both software and hardware. These problems do not fall onto the company who is using a computer service bureau. It would also be noted that the computer industry sees rapid advances continually and hence significant advances in hardware and corresponding software in short intervals of time are the rule rather than the exception.

The company with an in house computer system generally does not have redundant computer hardware. This means that if there develops a failure in the system which renders it inoperative the company is usually left without data processing capability until the system is repaired.

It should be noted that in addition to maintaining the computer system itself, the company with an in house system will have to maintain all supplementary systems as well. While it is true that greater security measures may be employed for example, they must also be maintained by the company. Similarly all personnel and any specialized training involved also falls under the responsibility of the company.

For a company using a computer service bureau there tends to be greater flexibility with respect to using the computer system capability required at the time. Variations in company requirements for data processing equipment are supplied as needed by the service bureau. A company with an in house system tends to find that at times their system is too small to handle their data processing needs and at other times they are paying for a computer system a portion of which is not even being used. Using a computer service bureau tends to give more financial flexibility to the company than does the purchasing of an in house computer system.

It is important to realize that as new lease/purchase schemes come onto the market the distinction between in house computer system and computer service bureau

tends to fade. For example, a company can lease a computer hardware system, "rent" the trained personnel from a software house, have both the system and the personnel on his own premises and subcontract out the maintenance of the system by means of a service contract. While this arrangement is not the same as a service bureau, certain differences are minimized.

Chapter 2

PROJECT CONTROL

2.1 Introduction

Project control is the process of making events conform to plans. Its application is based upon project time and cost schedules developed for the project and an information system that will provide data for comparing expected with actual performance. The information system measures, evaluates, and reports job progress comparing it with the performance planned. In this way, the manager is apprised of the nature and extent of any deviation. When deviations do occur, control is exercised by the manager who takes action he considers to be feasible and effective to correct the situation. Costs and time can quickly get out of hand on construction projects where production conditions are so volatile. Job monitoring must quickly detect such aberrations. Cost and time control information must be timely with little delay between field work and management review of performance. This gives the project manager a chance to evaluate alternatives and take corrective action while there is still an opportunity to rectify the situation.

2.2 Time Scheduling and Control

In general, there are few time restrictions imposed on the construction contractor other than the overall project completion time. Occasionally, contracts will stipulate completion dates of intermediate construction goals called milestones.

Failure to comply with contractual time requirements is a breach of contract, making the offending contractor liable for damages to the owner. Even if such damages were not at issue, the contractor's own self-interest dictates that he complete his projects on time. A reputation for timely project completion is an intangible asset of considerable value to a contractor. In addition, job overhead costs vary almost directly with time and expeditious job completion can mean appreciable overhead savings. Further, the end of a project frees equipment, men, and skilled supervision for another job.

The planning function is accomplished by dividing the project into small units called 'activities' and establishing the time sequence in which they will be performed. A detailed time study of the plan is then conducted, with adjustments to the plan being made

as necessary to meet the project completion date. On the basis of these studies the contractor establishes a calendar-date schedule of the anticipated start and finish times of each activity. The resulting time schedule, subject to periodic revision and correction during construction, is the essential basis for the day to day time control of the project.

When field operations begin, progress is normally measured by noting those activities that have been completed and estimating the times required to complete those that are in process. Time control is established by measuring and reporting field progress at regular intervals as construction goes along and taking remedial action to correct any divergence from the established schedule.

2.3 Cost Scheduling and Control

The main objective of a contractor's cost system is to check the actual production costs of on-going projects against the costs as estimated. A second objective is to obtain production rates for use in estimating new projects.

When a contractor prepares a competitive bid, lump-sum or unit price, he compiles a complete cost estimate of the job. The costs of labour, construction

equipment, materials, subcontracts, taxes, overhead, and surety bond are computed and combined with markup to arrive at the final bid amount. A similar "target estimate" is customarily prepared when a cost-plus contract is negotiated directly with the owner.

In order to genuinely effect cost control on a project, it must be possible to make prompt and frequent comparisons of actual and estimated costs of production. These costs must be determined in sufficient detail to enable project management to localize the trouble should cost overruns occur. Cost accounting is the process of obtaining actual production costs from on-going projects. This is accomplished by matching quantities of work done with payroll or equipment costs incurred during the same period. Unit costs of production are so obtained and used as a guide for the estimating of new work as well as the control of costs on current jobs. Because these costs are used for both estimating and cost control, the same elementary work classifications are used throughout the company's cost system. The cost code designations of these work items are permanently assigned, used uniformly by all company personnel, and do not vary from project to project.

The actual costs involved with the quantity of work accomplished on the site to date are obtained by measurement, inspection and calculation of the actual work done and the actual costs to date. These actual costs are then compared to the estimated costs and action is taken by the project manager to minimize any deviations that would tend to produce cost overruns.

Chapter 3

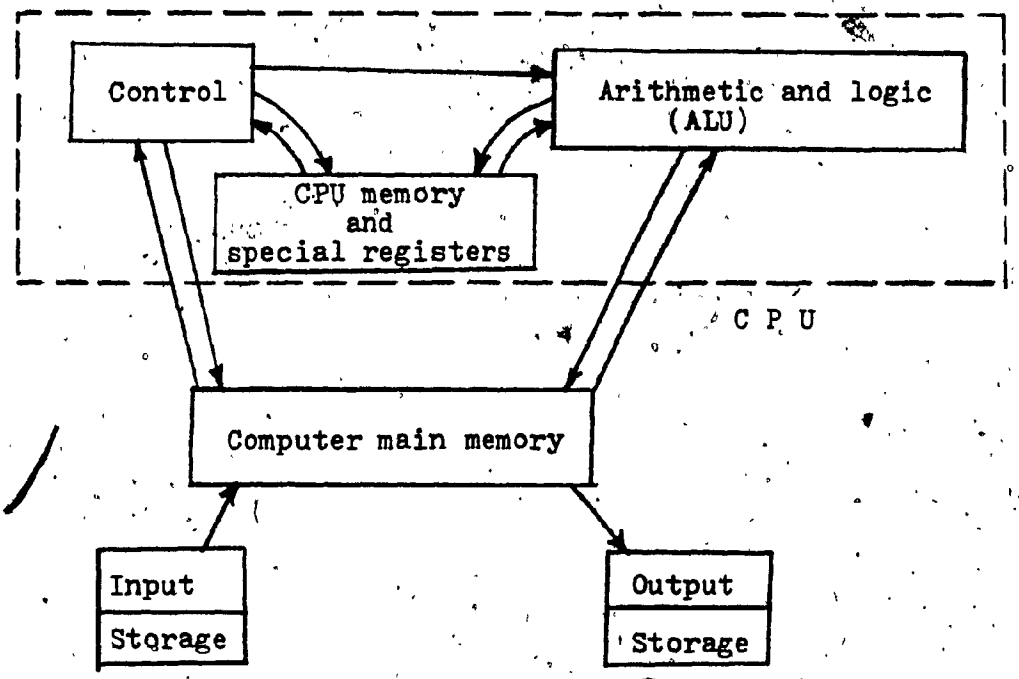
COMPUTER SYSTEM HARDWARE COMPONENTS

3.1 Introduction

A computer is an information processor. A computer can manipulate, sort, erase, and shuffle numbers that are stored in its electronic memory. Since it is a simple matter to let these numbers represent characters and symbols, a computer can electronically organize and remember words. This means that computers can be used for hundreds of applications involving words and, thus, may have nothing to do with arithmetic.

One feature that allows computers to do the jobs that they do today is their amazing speed. A typical computer system will perform millions of operations per second. This allows a computer to use relatively inefficient and even clumsy methods to solve complicated problems.

Every computer system can be divided into the following major sections: control, arithmetic, memory, input and output (see diagram next page). Each of these sections and the devices used to perform these functions will be discussed below.



arrows denote information flow

Figure 3.1

FUNCTIONAL REPRESENTATIONS OF THE MAJOR SECTIONS OF A COMPUTER SYSTEM

3.2 Central Processing Unit

The control and arithmetic sections are usually combined to form what is called the central processing unit, or C P U.

Due to fabrication processes called large scale integration or L S I, whereby thousands of electronic semiconductors such as transistors etc. can be put on a substrate smaller than the size of a dime the C P U is usually packaged in a single chip and is called a "processor". For some medium sized or larger business computers this processor may consist of several integrated circuit chips packaged on a printed circuit board instead of just one chip.

This processor is the actual brain of the computer.

The C P U contains:

1) a memory (usually a read only memory or R O M)
2) special register groups
3) the control section
4) the arithmetic and logic unit or A L U

The computer in its most basic form is a collection of electronic devices which act as switches. These switches react to signals which specify one of only two

states, i.e.--'on' or 'off'. The human operator would find programming in this level language too long, tedious and error prone. More human oriented and so called higher level languages were developed to allow programmers to write programs in languages more suitable to them.

There are two main steps involved in translating a higher level language (e.g. Basic, Fortran, Cobol, etc.) into a form whereby it can be utilized by the computer. The first step is to translate this higher level language into a machine code. This is done by a 'compiler' or 'interpreter' which is a manufacturer-produced program which does translation of this type.

Machine code is a very low level language consisting of the most simple instruction set for that particular processor. This instruction set is designed into the processor and is usually not alterable after the processor is manufactured.

This machine code in turn must be translated into a sequence of pulses which will direct the processor to electrically position its switches so that the desired operation is performed. The information required to translate the machine code into pulses is stored in the memory of the C P U. (R O M: item 1, listed above).

There are also special memory locations called registers (item 2, listed above) which contain one word or location 'address'. These registers are used for internal housekeeping chores such as remembering or 'pointing' to the location of the next instruction of the user's program which is to be executed. This is done so that the computer will not lose its place when it is reading and executing the instructions of a program one at a time.

It is the controller section of the C P U (item 3 above) which directs the computer when to fetch the next instruction, how to decode and execute it, and where to put the results.

When the instruction requires some arithmetic or logical manipulation it is the A L U (item 4, above) which is designed to perform these operations. Logical operations are those which compare, select, reference, etc. the bits (elements) of a data word considering these elements to be only ones or zeroes (i.e.--on states or off states) without regard to the actual numerical value.

Arithmetic operations are those standard mathematical manipulations that are based on the numerical values of the data.

It should be noted that in many functional representations the C P U memory and special registers are not shown separately but are included in the A L U. They are shown as separate here to more clearly demonstrate the functions of the computer.

The speed of operation of the C P U will vary from one manufacturer to another. The speed of operation of the C P U will usually determine the speed of operation of the computer calculations. This is so because the other factors such as memory access time (the time it takes to fetch a data word from memory) are not usually the limiting ones.

Advances in design and fabrication of electronic devices are such that the C P U, the brain of the computer system, is neither the largest nor the most expensive component in the system. Some peripheral devices can cost several times that of the C P U itself. In addition it appears that as advances in design and fabrication of electronic devices continue to be made cost per unit of computing power will continue to decrease. This is not necessarily true of the peripheral devices which are in large part mechanical.

3.3 Memory

Besides the C P U memory (R O M) discussed above, there are two other types of memory in a typical computer system. These are the computer main memory, called memory, and the external auxiliary memory, called storage.

These terms of memory and storage are not standardized and are sometimes used interchangeably. Memory and storage are used to store the programs and data of the user in preparation for, and during, execution.

The computer main memory is a very important and expensive part of the computer system. The main advantage of memory is its fast access time which allows the computer calculations to proceed at a rate governed by the C P U speed of operation. The main disadvantage of memory is cost. It is significantly more expensive than is storage.

The computer main memory is generally housed in the same enclosure as the C P U. It is typically a temporary usage, semiconductor memory called a R A M (for random access memory). It is more properly called a read write memory (R/W M) since R O M is also random access, but industry standard seems to have developed

to calling this memory a R A M. The size of the R A M is typically 32 K to 64 K where K here refers to 1024 bytes of data (A byte is a unit of data eight binary digits in length). Thus 64 K is equivalent to 65,536 bytes of memory.

Storage media is used to store large amounts of data economically. In addition where memory is usually volatile, storage is non-volatile; that is, if the electrical power input to the system is removed, the contents of memory will be lost, whereas the contents of storage would not be affected. Storage media is usually used for backup (redundant) data files.

Generally the memory of the computer is its working facility. It reads from storage that block of data which it wants to use or manipulate and then writes out this processed data to storage.

Storage media includes punch cards, paper tape, magnetic tape, and disks. These are discussed in section 3.6 (Mass Storage Devices).

3.4 Input Devices

3.4.1 Introduction

An input device is a peripheral which permits data to be input to the computer main memory for use by the computer.

Computers can be connected to electronic circuits that change analog information such as temperature, speed, fluid flow, etc. into binary form. These circuits are called analog-to-digital (A / D) converters. These types of inputs would normally be found in situations where the computer is used for process control but not project control.

There are also devices called light pens and digitizers.

A light pen is a rod with a light sensitive device on its tip. When this penlike device is pointed at information displayed on the C R T screen it detects light when the beam passes within its field of view. In this way the operator can add, delete, or transmit information under programmed control to the computer.

A digitizer is a special sort of analog to digital device whereby a curser is moved over a drawing which is positioned on a special board. This information is converted to digital form and is entered into the computer. In fact this digitizer performs under software control the inverse function of a plotter (to be discussed under section 3.5.4, Plotter).

Although many different kinds of input devices exist they tend to be specialized and rarely find their way into the typical business system. The standard type of input devices found in a business environment are a keyboard and a storage media reader, such as a disk reader.

3.4.2 Keyboard

A keyboard is often a separate unit. It may however be incorporated into a terminal such as a C R T (cathode ray tube) display unit. For business purposes a keyboard will usually have 26 upper case letters
26 lower case letters
10 numerals
approximately 30 special characters (*, ?. :, (), %).
It may also have special computer characters or functions such as curser positioning, line feed, carriage return. Shift and control keys are used in combination with other keys for special functions.

There are also options available, two of which will be described. If two keys are depressed such that the first key is depressed, then the second key is depressed before the first key is released, this represents a potential problem area. Using an electric typewriter the second keystroke might be locked out.

Using a mechanical typewriter the second printhammer will hit the back of the first. In either case the second character would not print. When inputting to a computer however, it is possible to arrange for the computer to sort things out. This option is called rollover.

If two keys are typed close (in time) together it is possible that one or more characters will require more processing time than is available. Some keyboards have an option wherein they have a memory to store characters until the computer is ready to receive them. This option is called a keyboard buffer.

3.4.3 Mass Storage Devices

Input devices of mass storage media are referred to as readers. There are: punch card readers
paper tape readers
magnetic tape readers and
disk readers, more properly called disk drives which are able to write to disk as well as read from disk. These peripherals will be discussed in section 3.6, Mass Storage Devices.

3.5 Output Devices

3.5.1 Introduction

An output device is a peripheral which permits

data to be output from the computer memory onto storage media to preserve the data or onto hard copy (printed characters onto paper) for use by human users, or onto a C R T screen for temporary storage for use by human users. In the field of process control output devices can also produce electrical or mechanical outputs to be used by other machinery.

For each input device there is an output device to perform the inverse function. Following is a listing of some input and output devices.

digitizer	plotter
light pen	C R T display
keyboard	printer

For all storage media cards, tapes, disks, there are devices to write onto the media as well as read from the media.

3.5.2 C R T Display

The C R T or Cathode Ray Tube display is a workhorse of the computer system industry. It is basically a television screen onto which is projected under software program control the output data and text of the computer, namely, programs and data.

Its main advantages are that it is silent and will

display text and graphics. It requires no paper and so is always available for use. It is not mechanically driven and so is relatively free from failure, adjustments, and is normally not affected by dust, dirt, or foreign bodies. With it the user can view 12, 16, 24 or more lines at a time, depending on the specifications of the particular C R T. In addition the speed of a C R T screen display is as fast as the electronics permit and is not limited to the speed of the mechanical print mechanism.

The main disadvantages of the C R T display are the limit of lines that can be viewed at one time and the fact that no hard copy (output onto paper) is produced.

Note that very often a video display terminal combines a C R T output with a keyboard input. In this case the comments of section 3.4.2, keyboard, and 3.5.2, C R T display apply.

Processing capability is increasingly being built into V D T (video display terminals). A'dumb' terminal provides the minimum equipment required to type programs and data into a computer and display the results on the screen. A 'smart' V D T typically has built-in memory that can store up to a full screen of characters. Some smart V D T have built-in processors which allow editing

and even some calculations without the necessity of tying up the computer.

Displays designed for producing designs, charts, graphs, layouts etc. on a C R T are called graphics displays or graphics terminals. They are basically high resolution versions of the standard V D U (video display unit). Some also have the facility to display in colour. Typically for businesses and in particular in the construction industry the increase in benefit will not justify the increase in cost of a graphics display.

3.5.3 Printer

A printer is a one way typewriter. It has no keyboard and hence can be used only to receive data from the computer but not to input data to the computer. Some terminals combine the benefits of a keyboard with a printer and in this case the comments of sections 3.4.2, Keyboard, and 3.5.3, Printer, apply.

Most businesses will require hard copy of reports, data, payroll checks, etc. A printer becomes indispensible to the business computer system.

Four main types of printers may be classified:

1) Thermal/Electrosensitive Printer
2) Band Printer
3) Matrix Printer
4) Line Printer

Thermal printers use a special paper and burn characters into it. The printing element has dots or segments which press onto the paper and the proper combination of segments is energized to burn required character. These printers are inexpensive and silent but offer a mediocre print quality, are slow speed, and require special paper.

Band printers operate as an office Selectric typewriter or teletype machine. Usually they are of the impact type. Three main techniques are used for the head:

1) Spherical or cylindrical element with all the characters
2) a daisy wheel
3) a matrix of needles. This case will be described in the next section (matrix printer).

An example of the spherical element is found on the selectric and an example of the cylindrical head is found on the teletype. This type of printer offers excellent print quality at acceptable prices but they are very slow and the teletype, for example, offers only upper case letters.

The daisy wheel printer uses a wheel with each character on its individual arm radiating from the center so that only a rotation is required. This allows

fast, quiet and reliable operation with excellent print quality. It is however more expensive than the other printers mentioned.

A matrix printer uses pins to print a pattern of dots on paper. The matrix is usually 5 x 7 dots or 7 x 9 dots. Fast, quiet operation and low cost are benefits. The main disadvantage is the relatively poor quality of the print.

A line printer prints a line at a time. The character set is on a belt or chain and is rotated along the full length of the paper. When a character passes a point on the line where it is to be printed a hammer will impact the character impression onto the paper.

A sprocket feed is required if business forms, labels, or checks are to be printed. No friction mechanism can provide the required vertical accuracy to position a large number of connected forms correctly.

3.5.4 Plotter

A plotter is a peripheral which under software control will plot or draw a graph, chart, schematic etc. of high quality. The grade of quality will depend on the resolution of the plotter. An X-Y plotter, for example, moves in horizontal and vertical directions so that the appearance and accuracy of curves will depend

on the size of the discrete steps of the plotter.

Although it might seem at first estimate that a general contracting firm might indeed have sufficient demand in its information system requirements for drawings, charts, etc., practice indicates that few firms make the decision to actually install one. The consideration must therefore be that the needs of the firm must be closely examined to ensure that the benefits derived will more than offset the cost of installing a plotter.

3.5.5 Mass Storage Devices

Output devices of mass storage media are those peripherals that can impart data or information onto the media. These include:

punch card keypunches

paper tape punches

magnetic tape recorders

disk drives which can write to disk as well as read from disk.

These devices will be discussed in section 3.6, Mass Storage Devices.

3.6 Mass Storage Devices

3.6.1 Introduction

The computer main memory is limited in size both due to cost and architecture (construction and design) of the C P U. If for example, the C P U can handle an address sixteen bits in length then the total adressable memory is a maximum of 2^{16} = 65,536 memory locations (64 K where K =1024 locations). Note that of this 64 K some of this space is used for the system software and is not available for use by the user. Because of this size limitation and also because the main memory is usually volatile (it loses the contents of memory when main electrical power is removed) a permanent expandable medium is used to store programs and data.

Usually information is stored into units called records. Records are then grouped by idea or function into files. Logical records are units of information (for example, one name and address of a subcontractor of a list of names and addresses of subcontractors) which are identified by user function. Physical records are the actual locations in the bulk storage media. One logical record may be stored in several physical records and it is up to the computer to cost them out.

Similarly a logical file is a group of logical records and a physical file is a group of physical records.

3.6.2 Disks

One major advantage of using a disk rather than cards or tapes is that the computer can move directly to the area where the information or data is stored without the necessity of reading through or moving the media from the starting point through to the destination.

Floppy disk units are popular with microcomputer systems. The floppy disk resembles a record and the name floppy arises because they are soft and bend easily. There are two sizes of floppy disks. The regular size is 8 inches in diameter and stores approximately 256 K memory locations. The "mini floppy" is 5¼ inches in diameter and stores approximately 100 K memory locations. There are also double density versions which store twice this amount.

For business systems floppy disks are generally not suitable and large rigid disk units are usually used. Rigid disk units store a great deal more information than floppy disk units, but they are more expensive. They are, however, much more suitable for business systems because the cost per unit of information is much lower for a rigid disk unit as compared to a floppy disk unit, and also the rate of information transfer is much faster. A rigid disk can store

approximately 40 times the information as can be stored by a regular 8 inch floppy disk unit.

The format of information storage on a disk is as follows: The disk is divided into concentric circles called tracks and the tracks are divided into units called sectors. A hard sectored disk is one where these sectors are delineated by holes or other physical means. Soft sectored disks are those where the sectors are delineated only by software programs.

3.6.3 Magnetic Tape

A less expensive means of bulk storage than a disk drive is a magnetic tape drive. Small units could be cassettes while larger units are of the reel-to-reel type.

The major disadvantage of magnetic tape media versus disk media storage is that tape is a sequential type of access to physical records, rather than the disk type of random access. This results in problems when trying to read and write onto the same tape or change information on a tape. There are normally separate units and tapes for the read and write functions.

Magnetic tape also tends to be less reliable than disk units and so redundant recording methods are in use to minimize the effects of errors. This, of

course, decreases by half the amount of useful storage available to the user.

3.6.4 Paper Tape

There was a time when paper tape represented the only low cost means of storing computer information, but today magnetic tape is approximately the same cost and is significantly faster.

Information is stored on a long thin paper tape by punching holes across the paper tape. Every row consists of eight positions. Each hole corresponds to a bit and each row corresponds to a byte of information.

The main disadvantages of paper tape are

1) sequential access
2) slow speed of information transfer
3) paper tape is erasable (by typing eight holes in the row) but information cannot be changed.

Two thousand feet of paper tape will store the same amount of information as a single 90 minute cassette or one side of a single density floppy disk.

Read write times for paper tape will vary between 10 and 100 c p s (characters per second). For magnetic tape the read write rates vary between 100 to 1000 c p s, and for floppy disk between 1000 to 10,000 c p s.

For rigid disks these rates can exceed 1,000,000 c p s.

3.6.5 Punch Cards

A single punched card, in the most popular format, can hold a maximum of 80 characters. They must be punched on a keypunch machine. This is a machine with a keyboard and card handling capabilities. Whatever the operator types on the keyboard is punched onto the card and is also printed or typed onto the top of the card so that the operator can read it. Characters are coded by different combinations of holes punched per column.

The rate at which cards can be punched limit their use to low volume or low speed applications. Punched cards are sequential and so access time is long unless a multiple card feed system is coupled to the processor.

Punched cards are not popular with small business systems.

3.7 Mode of Operation

Operation of the computer (executing programs or processing data) may be done on line or off line with respect to the data input.

Batch processing is the off line mode of operation

whereby items to be processed are coded and collected into groups prior to processing. In this type of operation when data is prepared from a terminal it is not entered directly into the computer but is typed or stored onto a mass storage medium such as punched cards. At specified time intervals all jobs are collected together and run.

Demand processing is the on line mode of operation whereby the user enters information into the computer and it is processed as quickly as it becomes available. This is a real time system which minimizes the need for storage of any appreciable amount of unprocessed data.

It is possible for a system to operate in both modes--batch processing and demand processing--during the same time period. Background processing is the arrangement whereby the computer will do low-priority work when higher priority or real-time entries are not occurring. Batch processing is often treated as background processing which can be interrupted on orders from terminals or inquiries from other units.

4. INFORMATION REQUIREMENTS OF CONSTRUCTION FIRMS

4.1 Introduction

The information requirements of construction firms will be highlighted by considering as an example a firm whose annual volume is thirty five million dollars, represented by approximately three projects totaling $15,000,000 and twelve projects totaling $20,000,000.

It is also conceivable for such a firm to be in control of one major project of say $20,000,000 whose completion spans three years. This type of project requires information storage and processing of a degree which has implications for the computer system hardware configuration requirements particularly in the area of data storage. This will be considered later in this report.

Project control consists, in essence, of

1) planning the execution and completion of a project, i.e.--the design, financing, manpower, equipment and materials required, including the time scheduling as to when these items would be required,

2) monitoring the actual execution of the project and comparing the actual progress of the project with the estimated progress of the project,

3) detecting differences between the actual and the estimated and taking action to minimize these differences.

Requirements for the firm include:

1) job estimating on roughly 150 to 200 jobs per year (firm is awarded only 7% to 10% of jobs quoted on). Job estimates include cost distribution.

2) On jobs awarded, detailed financial progress report estimates (job costs) and time schedules must be made. That is, anticipated expenditures per unit time (week, month) are calculated.

3) The manpower both in terms of workers and project management and design personnel must be calculated and scheduled.

4) The equipment and material required for the project must be accounted for to ensure timely procurement of the necessary items. Consideration is also given to the relative merit of purchasing or leasing the required equipment.

5) Short cycle scheduling must be monitored to ensure that resources are available to perform the necessary activities.

6) Inventory of equipment and materials on site must also be maintained to ensure proper billing and payments.

7) Physical progress of work on site must be monitored to ensure proper progress, billing and payments.

8) Change orders, chargebacks and changes resulting therefrom must be closely monitored. This would include changes in inventory of equipment, materials, manpower, scheduling and possible conflicts due to previous obligations.

9) Provide reports, charts, graphs etc. as necessary (to be described in chapters 4 and 5).

Presently job cost reports in our example firm are broken down by labour, permanent material, consumable material, supplies, company equipment, rented equipment and subcontractors. Each report takes two man days and all reports are prepared serially with the result that the last report is submitted three weeks after collection of data. This results in delays in detecting and therefore correcting variances from the job estimate. It is important to note the emphasis on timeliness of reports. The earlier deviations from estimates can be detected and analyzed, the earlier can corrective action be implemented and the greater will be the saving in cost and/or program scheduling.

Two further requirements of the firm therefore emerge:

10) All reports that are prepared must be compiled and presented within a short interval of time, in the order of three or four working days.

11) When a particular variance from estimate is detected a detailed breakdown of summarized cost must be quickly available for purposes of analysis of the variance.

For purposes of project control the proposed computer installation shall provide

--weekly unit cost reports based on actual labour costs, quantities of material received extended at purchase order price, equipment usage and rental subcontracts,

--monthly cost report showing all costs vs estimates including physical progress and unit costs as well as all change orders and back charges,

--monthly project financial status report including a profit and loss statement showing total estimated costs, actual costs to date, projected cost to completion, billing status, change order costs and change order billing status.

--weekly report comparing the actual physical progress (completion to date) against the estimated schedule of completion to provide the input to facilitate time s chedule verification.

It should be noted that the timing and detail of the reports mentioned above are based on mean requirements of the sample firm. The actual timing and detail of reports to be produced could change with the size and type of the project and even the norms and desires of the company. The intervals chosen here are meant to be illustrative.

4.2 Data Inputs

Type of information (data) inputs required for project control include

A) materials received and invoices and payments
B) manhours worked
C) equipment used and of what type
D) change orders and back charges incorporated
E) sub-contracted work performed.
F) measure of actual work accomplished
G) original estimates of project completion with regards to time and cost.

On a continuing basis these data are compared to the estimated project cost breakdown and timing schedule to highlight any deviation from plan and there-

by to initiate corrective action. Clear and accurate timely computer data input is a prerequisite for the successful operation of the system.

4.3 Data Outputs

Type of data outputs related to project control:

A) catalogue of equipment

B) equipment utilization reports

C) financial status of equipment including

   a) operating cost and cost to date

   b) lease termination

   c) buy out warning

D) Sub-contractor status report

E) aged receivables

F) invoice and payment status

G) audit trail--supporting entries and adjustments

H) cost history and detailed costs to date

I) cost comparison to estimated values

J) profit and loss statement per job

K) possibility of graphs and drawings in reports

L) provision is made for on request reports and on-line file interrogation via the input terminals for such items as stock of material inventory, etc.

M) measure of actual work accomplished

N), original estimates of project completion with regards to time and cost and/or differentials between estimated and actual progress.

4.4 User Profile

The materials received are indicated by receiving slips. Invoices and payments are generated from accounting information. Manhours worked are entered via time-cards, equipment used (hours and type of equipment) from operator time cards and equipment slips. Change orders, back charges, subcontracted work performed are recorded on forms made for this purpose.

The information re the received materials would come from the store clerk. Invoices and payments come via office accounting clerks; manhours worked via workers time cards, equipment used could come via the site superintendent who could be approving the use of the equipment on site. Subcontracted work performed is calculated from on site investigation of project progress. This is done by the engineer, architect, general contractor and/or sub-contractor.

The data outputs can frequently be used by more than one user. General catalogue of equipment

is used by Project Management and upper management for ongoing review. Equipment utilization reports, financial status of equipment are also reviewed by project management and upper management. Equipment lease termination, buy out warning can also be used by the accounting department. Sub-contractor status reports are generated from inspections by the engineers and architect, and are used by project management and upper management for monitoring. They are also used by the accounting department after approval of payment is made. Invoices and payments are used by the accounting department and project management and upper management staff. Job cost history is used by project management and upper management staff to aid control of scheduling, and at a future date by estimating staff to help calculation of future similar job estimates. Graphic displays (charts, graphs, drawings) could be used by any of the above. Examples of graphic displays are given on the following pages.

Note that this system would have the capability not only to record and reproduce all actual reports (weekly, monthly, etc.) and their comparisons to the original estimates, but after the job is completed

it would use the actual project costs and scheduling and regroup them into the format of a project estimate or tender bid. This data could then easily be used for verification purposes when estimating future project costs. All reports including the project estimate based on project costs would be stored on permanent file.

By having the information readily available in easily usable format it can be used to verify future prepared estimates. If information is not in easily usable form, even if it is available in total or in part, experience indicates that it is much less likely to be used.

On the following pages examples of graphic displays are recorded and discussed. Potential users of these representations are also discussed.

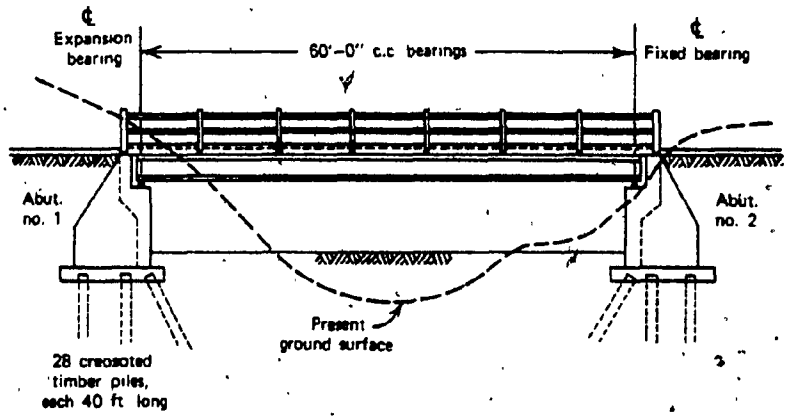


Figure 4.1 Bridge Profile (Ref:7)

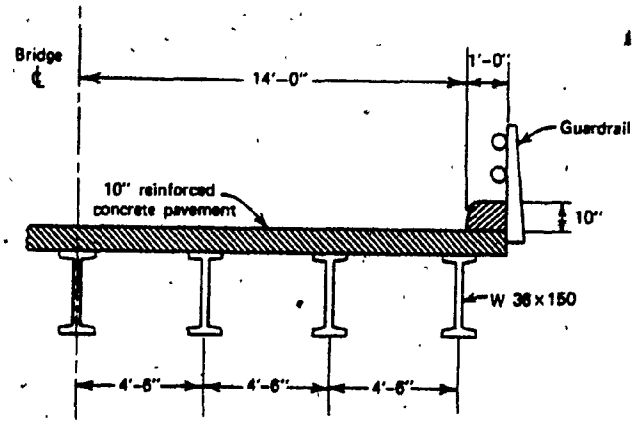


Figure 4.2 Bridge Transverse Section (Ref:7)

These drawings can be produced as shown above by means of a plotter.

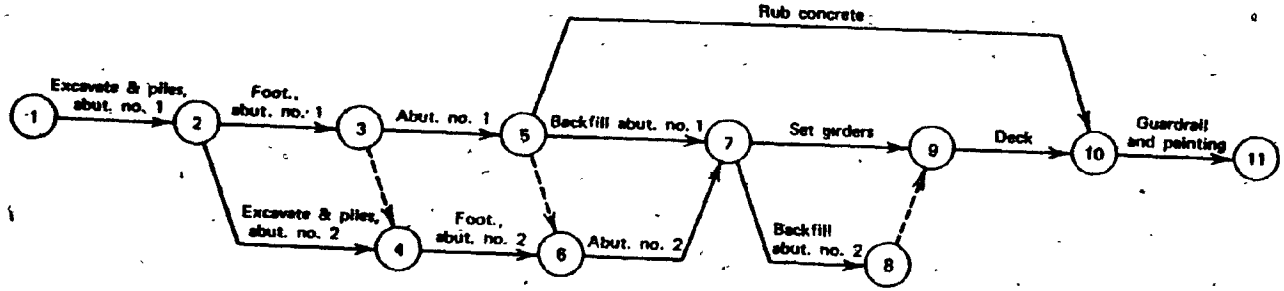


Figure 4.3 Summary Arrow Diagram (Ref:7)

The above C P M chart can be produced as shown above by means of a plotter.

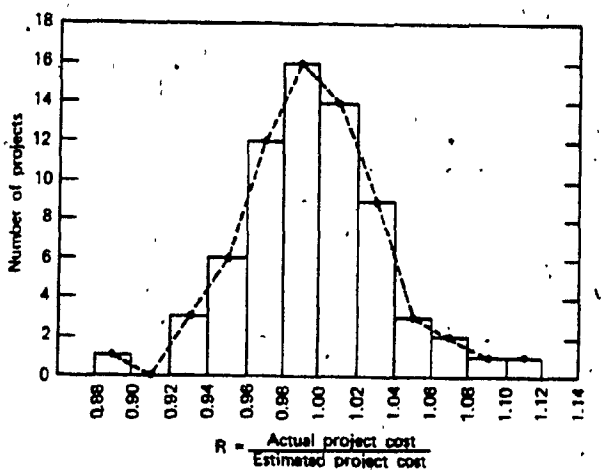


Figure 4.4 Histogram of R-Values (Ref:7)

This type of graph or bar chart can be produced as shown above by means of a plotter. A close approximation of the above representation can be made using a printer, where instead of solid lines to form the bars, dots (periods), for example, could be used. Instead of a dashed line, other special characters--asterisks, for example, could be used to graph the midpoints on the bars.

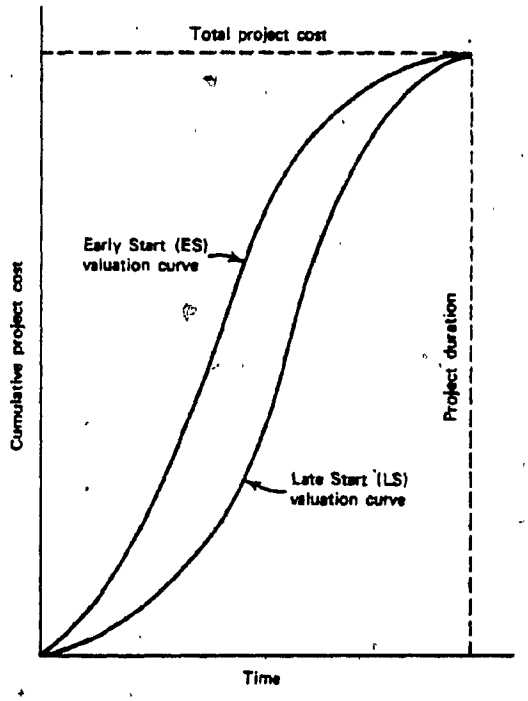


Figure 4.5 Typical Form of Project Time-Cost Envelope (Ref:7)

This type of graph can be reproduced as shown above by means of a plotter. A close approximation of this type of graph can be made on a printer where instead of using solid lines to graph the values, special characters such as asterisks or dots (periods) can be used.

UNIT PRICE SCHEDULE

Item No. (1)	Description (2)	Unit (3)	Estimated Quantity (4)	Unit Price (5)	Estimated Amount (6)
1	Excavation, unclassified	c.y.	3,600	$ 1.20	$ 4,320
2	Excavation, structural	c.y.	350	7.70	2,695
3	Timber piles	l.f.	2,240	5.30	11,872
4	Concrete, foot.	c.y.	120	60.00	7,200
5	Concrete, abut.	c.y.	280	80.00	22,400
6	Concrete, deck slab	s.y.	200	18.00	3,600
7	Concrete, curb	l.f.	120	6.00	720
8	Steel, reinf.	lb.	120,000	0.29	34,800
9	Steel, structural	lb.	65,500	0.41	26,855
10	Bearing plates	lb.	3,200	0.60	1,920
11	Guardrail	l.f.	120	16.00	1,980
12	Painting	l.s.	job	3,120.00	3,120
	Total Estimated Amount				$121,482

Figure 4.6 Unit Price Schedule (Ref:7)

This type of table can be produced as above by means of a printer.

June 30	Initial expense	=	$ 953
	13 days indirect cost @ $219	=	2,847
	5-20	=	2,927
	5-60	=	531
	20-40	=	1,624
			$ 8,882
July 31	Initial expense	=	$ 953
	34 days indirect cost @ $219	=	7,446
	5-20	=	2,927
	5-60	=	531
	20-40	=	1,624
	25-30	=	4,402
	40-65	=	4,402
	Footing no. 1	=	5,647
	Footing no. 2	=	5,647
	Abutment no. 1	=	12,434
			$46,013
August 31	Initial expense	=	$ 953
	56 days indirect cost @ $219	=	12,264
	5-20	=	2,927
	5-60	=	531
	20-40	=	1,624
	25-30	=	4,402
	40-65	=	4,402
	Footing no. 1	=	5,647
	Footing no. 2	=	5,647
	Abutment no. 1	=	12,434
	Abutment no. 2	=	12,434
	95-115	=	314
	95-140	=	552
	112-140	=	552
	115-130	=	314
	120-125	=	20,812
	Deck	=	13,116
	135-150	=	55
	140-145 (one day)	=	414
	140-150 (one day)	=	470
			$99,864

Figure 4.7 Contractor Outlay (Ref:7)

This illustrates another type of layout that can be used to produce a table on a printer.

The preceeding pages show forms that graphic output can take. Whom the users of this information are will depend of course on what information is put into this form.

Figures 4.1 and 4.2 are drawings that could be used by engineers, architects and management. They could be used in reports to be sent to the client or to institutions from which financing is to be obtained.

C P M charts (Fig. 4.3) are largely used by different levels of management.

Figures 4.4 and 4.5 are different types of graphical representations. Actual versus estimated costs could be used by project management. Resource usage, actual work finished on a time schedule, or any other variables that can be graphed can be produced by these computer peripherals. The information content of the graphs will be largely determined by the users' needs.

Reference is made here to printers as well as plotters because while for a typical business system a printer is a requirement, a plotter normally is not. Adding a plotter to a business system requires particular hardware and software additions which represent a significant expense. Therefore it is advisable to be aware of the capabilities of the equipment that comprise the computer information

system. Certain printers are advertised as having graphic capabilities. This usually means that it is possible to form special (sometimes meaningless) characters through software programming and that the resolution of these printers is better than standard. That means characters can be placed closer together and/or in non-standard locations as distinct from a non-graphic printer. However both the graphic and the non-graphic types can be used to produce the types of graphs shown here. The difference in quality will largely be one of resolution (or coarseness).

Figures 4.6 and 4.7 represent tables. This type of information representation is standard in the industry and can be produced with a printer. Many types of information can be produced within this format and there will be correspondingly many classes of user for these data.

4.5 Computer System Benefits

Advantages and disadvantages of the computer system were discussed in Chapter 1. Specific benefits of the computer system will now be enumerated in view of the firm requirements identified.

The computer system is no more than a management

tool which is used to store, process and retrieve information. The value of the computer system resides in its ability to aid management in controlling job costs and revenues. In essence it can perform this function by making available the information required to enable management to make decisions and within the time limit necessary for management to take action be it to correct a problem or take advantage of an opportunity.

Benefits that would accrue to management through use of a computerized system include:

--monthly cost reports will be available three weeks earlier than those prepared in the typical manual system.

--cost reports of previous projects could be used to help verify new job estimates.

--all information required for support of estimates etc. is quickly and easily available, thus saving time and maintaining confidence in the figures.

--detailed consistent methods are incorporated to record cost transactions, material control etc., thereby tending to ensure that procedures are complete in detail and that information is accurately recorded.

Chapter 5

COMPUTER SUBSYSTEM REQUIREMENTS

5.1 Introduction

In section 3.6.1, Introduction to Mass Storage Devices, logical and physical records and files were differentiated.

The basic organization of a computer subsystem will now be examined. The terms of records and files are used as defined in section 3.6.1. A page referred to here will be one physical page of computer output. A byte is a basic unit of computer data. It typically represents one letter or one digit or one special character such as)*, ?, :, ;, /, . One kilobyte, kb, is 1000 bytes and one megabyte, Mb, is 1,000,000 bytes.

When an operator inputs one basic piece of information, such as an invoice being paid, this is termed an entry.

There is a tendency for business systems to be integrated. This means that when data is entered into one system it is transferred internally to all other systems which require this information. This is done without further human intervention. This reduces the amount of work required and also the possibility

of error. For example, when a progress payment is made to a sub-contractor this would be entered into the subcontractor file, the accounts payable system and the actual job cost file. When a system is integrated it is only necessary to enter this once and the other files receive this information internally. This is referred to as "internal" data inputs on the following pages.

The type of consideration and calculation that is required to determine the size of the computer records and files will now be examined. This report is meant to illustrate the type of calculation required and is not directly applicable to a particular firm. The figures used here are typical and are taken from representative industry experience.

To calculate the record size for one subcontractor

Sample

		Bytes used	Bytes allotted
Name			
Russell Concrete Flooring Inc.		30	40
16722 Uptown St.		16	30
Montreal, Que., H4X 2N3		20	30
	subtotal		100
Contract Information			
Project number	OFC 7392	8	10
Contract number	MFCR 602	8	10
Total value	$106,420.31	10	15
Invoiced	$21,400.00	9	15
Paid	$19,200.00	9	15
Payable	$ 2,200.00	8	15
Holdback	$ 1,920.00	8	15
	subtotal		95
Charge back number	0	1	10
Charge back amount	0	1	15
Change order number	A 70310	6	10
Change order amount	$23,169.00	9	15

Note that spaces and special characters ($.) must be counted separately when they are used. Generally dollar signs need not be entered when the figure entered is known to always represent money. The computer will automatically insert these signs where required in its printouts. Similarly the underlined titles are not entered or stored by the computer, but they are supplied

automatically on the printouts.

The typical business system may not store dollar signs or other repetitive characters per contractor.

Allowing for two contracts per contractor and six change orders or chargebacks per contract, the record size may be calculated to be

100 + 2(95 + 6 x 25) = 590, say 600 bytes

Based on company experience and goals allocate the number of records to be:

average number of active contractors per job

multiplied by average number of jobs

say, 10 x 15 = 150 active contractor records

Similar calculations to arrive at say 250 inactive contractor records.

Subcontractor

400 records 150 active

250 inactive

each record 600 bytes

The breakdown of the computer subsystems follows.

5.2 Equipment Subsystems

Functions

A) Maintain a file of equipment owned and rented over the last desired number of years.

B) create and maintain files and reports on:

a) cost of operation (summary)

b) utilization and down time/availability ratios

c) payment status/financing status

d) approach of lease buy out

e) termination of lease

Inputs

A)	equipment data	100 entries/month
B)	operators reports	500 entries/month
C)	cost data (from job costs)	Internal
D)	invoices and payments (from accounts payable)	Internal

Outputs

A)	catalogue of equipment (on request)	50 pages/month
B)	utilization reports	200 pages/month
C)	financial status	50 pages/month
	a) operating cost per hour	
	b) lease termination	
	c) buy out warning	
	Total:	300 pages/month

Files

A)	equipment file for owned and rented equipment	600 records

Major Control Applications

A) invoices and payments

B) equipment cost versus job equipment estimates

C) utilization and availability

D) lease buy out timing

5.3 Sub-Contract Subsystem

Functions

A) maintains a file of all subcontractors used over the last desired number of years

B) reports on sub-contract status

a) value

b) invoice payment status

c) hold backs, charge backs, change orders.

Input

A) sub-contractor data	100 entries/month
B) invoice and payment data (from accounts payable)	(internal)
C) change order, charge back (from job costs)	(internal)

Output

A) sub-contractor status report	150 pages/month

File

A) sub-contractors (150 active and 250 inactive)	400 records

Major Control Applications

A) matching of payments vs. contract value (i.e.--work done)

B) follow up "overdue" charge backs

C) tracking of change orders, chargebacks and hold backs

5.4 Cost Distribution Subsystem

This is the major subsystem within the overall company control of projects. It receives all of the project related costs and classifies them according to job or project. These costs are then distributed to the relevant job cost subsystems and in the appropriate cost breakdown. The information available from this subsystem is valuable when considering project management and control staff organizational setups. The size of this subsystem has a major impact on the size of the computer M I S requirements.

Functions

A) accepts cost input for jobs only from payroll, accounts payable and equipment subsystems,

B) summarizes detail costs by job control and general ledger, account number,

C) prints audit trail reports to support automatic entries

D) maintains a file of all detail cost records and on a request basis provides detailed costs,

E) prepares cost comparison reports based on job and item number input on request.

Inputs

A)	Payroll	internal
B)	material equipment and sub-contract costs (from A/P)	internal
C)	distribution adjustments	200 entries/month
D)	cost control G/L cross reference	internal
E)	equipment costs	internal
F)	direct staff	50 entries/month
G)	out of country	300 entries/month

Outputs		Pages
A)	audit trail	10/month
B)	detail costs to date	200/month
C)	cost comparisons per line item	100/month
D)	cost history	200/month
		say 600/month

Files

Historical detail costs and adjustments

4000 records/month x 24 months	=	96,000 records
1000 records/month x 36 months	=	36,000 records
	Total:	132,000 records

Note that a period of 36 months is used here because of the consideration that a particular project could last 3 years.

These files include all costs for all the projects. Since they are the source of information to other subsystems such as payroll, job costs (equipment and material, for example), subcontracts and even general ledger and other accounting systems, they are complete and detailed. They comprise a complete record of the costs of each project from its inception through to its completion. As well as all costs regarding current activities, these files store detailed historical information such as subcontracts which have been completed, inspected and paid in full. All of these costs are stored until the project is completed.

Major Control Applications

A) audit trail of costs

B) listing of adjustments and entries

5.5 Job Control Subsystem

This subsystem is the major one used for individual project control. This subsystem contains the information required to monitor the actual and estimated cost and the actual and estimated time scheduling on a per project basis. It receives the cost information from the cost distribution subsystem and directly receives input information with regards to scheduling, work progress, change orders etc. All

reports and schedules are dated. This results in the work progress, for example, being monitored on a time basis. Comparisons of the actual and estimated time scheduled work progress allow for project control actions to be implemented. Note that the cost distribution system receives the information regarding change orders etc. from the accounts payable subsystem as they are paid.

Functions

A) maintains file of estimated costs, actual costs, units of production for each line item for each job.

B) change orders are maintained as line items complete with a status code vis a vis approval status

C) unit costs are calculated where appropriate

D) cost data broken down as to:
   a) labour
   b) permanent material
   c) consumable material
   d) equipment (owned and leased)
   e) sub-contracts

E) equipment is maintained as job line items

F) special conditions are flagged
   a) change order with no cost

b) actual over estimate

c) large variances in unit costs.

G) all changes to a job like change orders and back charges will be forwarded to payables, receivables, sub-contracts

H) no restrictions as to the number of line items per job or the number of items controlled on a unit basis

I) produces weekly unit cost reports

J) produces monthly cost reports.

Inputs

A)	all costs (from cost distribution)	internal
B)	estimates (cost and units of production)	200 pages/month
C)	change orders	100 pages/month
D)	charge backs	20 pages/month
E)	extra work orders	10 pages/month
F)	units of production	400 pages/month

Outputs

A)	weekly costs	100 pages/week
B)	monthly costs	200 pages/month
	Total:	600 pages/month

Files

A) original line items

100 lines (average)/job x 15 jobs = 1500

B) change original line items

200 lines (average)/job x 15 jobs = 3000

C) equipment 250 = 250

4750

say 5000

Major Controls

A) cost coding and adjustments screened and systematized

B) costs can easily be supported by

a) description audit trail

b) detail cost report

C) special conditions flagged.

Chapter 6

COMPUTER SYSTEM CONFIGURATION CONSIDERATIONS

6.1 Introduction

The computer system to be chosen here is constrained by the fact that selection is made from commercially available hardware. Further constraints result from detailed consideration of the system's desired objectives. This would include the estimated volumes of input, output, computer memory requirements. The computer memory requirements (as distinct from mass storage) would largely be influenced by the amount of data that must be available for immediate access. Hardware choice is of course a function of specialized performance objectives, for example, graphics.

In any computer system, a design objective is to eliminate or minimize redundancy. This is done to help minimize memory size requirements and also to help minimize effort required for the data entry. Integrating system inputs effects a large reduction in redundancy as noted above. This feature has been assumed in the discussion to this point. For example, to enter labour cost data into the payroll, cost distribution subsystem, and job control subsystem it is necessary to enter the data only

into the payroll subsystem; the other subsystems acquire the data automatically and internally within the computer system. Because of this, in the discussion that follows the inputs to payroll and other such subsystems will be discussed even though the consideration of the subsystems themselves is beyond the scope of this report.

6.2 Estimated Quantity of Data Entry

The following figures represent the totals for the requirements of the subject firm discussed. In an actual practical situation they would of course have to be calculated according to the needs of the actual firm.

Equipment Subsystem	Entries/month
A) Equipment data	100
B) operators' reports	500
C) cost data (see cost distribution subsystem)	
D) invoices and payments (see accounts payable)	

Sub-contract Subsystem	
A) subcontractor data	100
B) invoice and payment data (see accounts payable)	
C) change order and chargebacks (see job control)	

Cost Distribution Subsystem

A) labour (see payroll)

B) material, equipment and sub-contract costs (see accounts payable)

C) distribution adjustments 200

D) cost control/GL cross reference (see general ledger)

E) equipment costs (see accounts payable)

F) direct staff 50

G) out of country staff 300

Job Control Subsystem	Entries/month
A) all costs (see cost distribution subsystem)	
B) estimates	200
C) change orders	100
D) charge backs	20
E) extra work orders	10
F) units of production	400

Accounts Payable

A) purchase orders	1200
B) invoices including sub-contracts	2800
C) adjustments	400
D) supplier data and cheques	600

Payroll	Entries/month
A) employee data	150
B) time cards	3200
C) adjustments	450
General Ledger	
A) ledger entries and account date	100
TOTAL TRANSACTIONS	10,880
CONTINGENCY (this is not expansion potential)	1120
	12,000

6.3 Estimated Quantity of Data Output

Report Volume	pages/month
Equipment	300
Subcontracts	150
cost distribution	600
job control	600
TOTAL	1650
CONTINGENCY (this is not expansion potential)	250
	1900

6.4.1 Computer Hardware Capacity Calculations

Note that as was mentioned earlier this firm quotes on 150 to 200 jobs per year of which 90% to 93% are not awarded. There is no allocation in

this allowance in this system to store each of these quotes on the computer memory. This is because automatically those jobs that are awarded to the firm will be entered into the system. Those jobs which are not awarded to the firm (which initially is all job estimates since it is not known which jobs will be awarded and which ones will not be) are prepared in the firm and put into the form desired by the client using the computer or a manual system. These job estimates can then be stored in the form that was presented to the client and with all the notes and take offs that were used to arrive at this estimate.

The following calculations are designed to identify hardware constraints that would result from the volumes of input and output data and the time requirements to obtain access.

6.4.2 Data Entry

$$12{,}000 \frac{\text{entries}}{\text{month}} \times 70 \frac{\text{keystrokes}}{\text{entry}} \times 1 \frac{\text{manhour}}{500 \text{ keystrokes}}$$

= 112 manhours/month

To calculate the minimum amount of necessary hardware, assume all entries by a skilled keypunch operator the requirement for data entry is:

112 manhours per month

Per month available time is

22 days/month x 6.5 hours/day

= 143 hours per month

This indicates that one terminal would be occupied 80% of the time.

6.4.3 Hardcopy Output

$$1900 \frac{\text{pages}}{\text{month}} \times 50 \frac{\text{lines}}{\text{page}} \times 1 \frac{\text{month}}{143 \text{ hrs.}} \times 1 \frac{\text{hour}}{60 \text{ min.}} = 12 \frac{\text{lines}}{\text{minute}}$$

The minimum requirement for a printer which will be operated only during the company business hours (no overnight printing runs) is 12 lines/minute.

There is an assumption here that data will be available whenever the printer is free, i.e.--a resource leveling of data output is maximized. In practice this does not happen and the printer may be used as little as 20% of the time that is available. It is of course still required to produce the required volume of output.

The minimum printer capacity therefore becomes:

12 lines/minute x 1/20% = 60 lines/minute.

6.4.4 Disk Capacity

To accomodate all active files simultaneously the disk capacity is calculated as follows:

	Megabytes
Equipment Subsystem	
600 records x 400 bytes/record =	.24
Subcontract subsystems	
400 records x 600 bytes/record =	.24
Cost distribution subsystem	
132,000 records x 50 bytes /record=	6.6
Job control subsystem	
5000 records x 400 bytes/record =	2
TOTAL DATA	9.08
free space overhead	2.9
operating system	2.0
	14.0

Minimum disk capacity is 14 megabytes.

6.4.5 Computer Internal Memory

operating system	10 K
data entry	15 K
programs (High level language)	39 K
	64 K

Chapter 7

CONCEPTUAL COMPUTER HARDWARE SYSTEM ANALYSIS

7.1 Introduction

The calculations in the previous section were done to identify hardware constraints. The computer hardware system must be configured within these constraints, but based on the requirements of the firm.

In order to gain the desired and planned benefits from the system, it must be designed so that it is easy to use by all so that it will be used properly and as required.

Data input is required from each job site, for example materials received, equipment used, labour costs etc. This data can be entered into the system

A) in an interactive mode, through a regular or 'smart' video display terminal or a terminal with hardcopy capability or

B) in a batch mode using only forms which are filled out on site and are then keypunched into the system on a daily basis.

The data could also be typed onto a storage device on site and entered into the system on a daily basis.

Data may be required on each site. Examples of this are reports, change orders, back charges

approvals, available resources etc. This data can be transferred on request from a terminal on site to a hardcopy printer also on site, or requests can be received from the site and the information would be prepared and sent to the site the next day or on a periodic basis. Similarly graphs, bar charts, etc. can be produced with a plotter.

7.2 Representative Systems

The minimum system hardware requirements for this firm would be one computer (C P U), one C R T terminal, one printer, one dual disk drive. This system is illustrated in the schematic in figure 7.1 with representative figures as discussed in section 6.4. All of this hardware would be housed in the company's main office and the system would work in the batch mode. All figures from the site would come from filled out forms. All reports and data out to the site would be available on a next day basis.

Note that a dual disk drive (a drive that operates two disks) is recommended to facilitate copying data from one disk to another. Back up disks are normally made and updated periodically as security against loss of data.

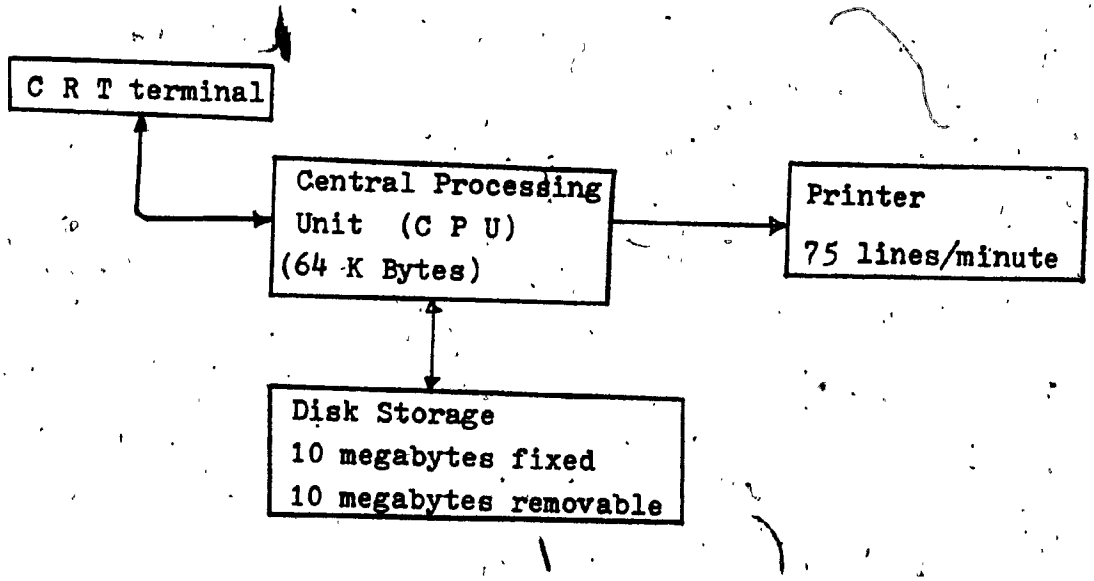


Figure 7.1 Minimum System Hardware Requirements

The next stage of system hardware sophistication would be to have a remote terminal. That is, a C R T terminal on the site with an accoustic coupler modem. The accoustic coupler modem is a device which enables communication to be made from the terminal on site to the C P U in the company main office by means of standard telephone lines. This eliminates the need to run special lines to each site when the project starts.

A terminal on site would permit on site personnel to ask for information and receive it immediately on the screen. On site personnel could also input data directly to the computer. An interactive mode of operation would then be feasible Only information that could be projected onto the C R T screen could be sent out to the site. This might be: "has the change order been approved?" or "for this subcontract what material is called for and to date what has been received?" A printer on site could increase this capability.

An on site printer would allow the transmission to the site of hard copy output. Information which is to be retained for further reference or which is required at a location on the site removed from the terminal itself can now be produced by the printer. This might include subcontractor work schedules, anticipated bills of materials, even portions of contract documents, etc.

It is possible to increase the site facilities to the level of the main computer installation. An on-site plotter would allow the production on site of drawings, charts, or graphs. This might be of interest where it is desirable to very quickly receive on site the latest revisions or updates. Punch card readers or magnetic ink readers might be of interest so that

the data from the time cards of the workers might be read directly into the computer C P U. These cards would, of course, have to be suitable matched to the computer reader peripheral. There could even be on site a small processor (C P U) which could do payroll or other calculations.

The size of the individual projects and the distance or ease of transmission of information and hard copy by means other than the computer system will be significant factors in determining the usefulness of the computer system peripherals on site. Conditions of a large project, such that transmission of information to the site is difficult or expensive by non computer system means, and being such that it is important to receive on site printouts or diagrams would have the effect of increasing the value of having the computer peripherals on site. Conditions such that the site is easily reachable from the office would tend to decrease the value of having the computer peripherals on site. This must be examined in light of the firm being considered.

Chapter 8

RECOMMENDATIONS

8.1 Introduction

It should be reiterated here that the scope of this Major Technical Report has been limited to project control and as such has not viewed or considered the complete application of a computer system. It cannot therefore address itself to the design of the optimum computer system for the firm. It does however highlight the type of consideration and analysis that should be undertaken before the decision to implement a computer system is finalized.

With this in mind recommendations are presented in section 8.2.

8.2 Recommended Computer System

Our subject firm is considered to operate in a manner whereby hard copy is easily available from the office to the site. And so a printer, plotter etc. is not necessary on site. It is also considered that having information immediately available to the site when required is a requirement which is strong enough to merit having a terminal on site. Hence the following recommendations are made.

A video display smart terminal should be put on each project site. Communication to the main computer system is done via telephone lines so that no additional wiring is necessary (acoustic couplers can be used, for example). However data input should be in the batch mode, that is, forms should also be available on each site and the user at each site can decide to use either the terminal or the forms to input required data into the system. This is done to make the system easier to use by the user since most construction people on site are not skilled at typing. Data which is entered via terminal would only be stored in a buffer stage in the central office and daily checked for syntax and other errors by an operator and entered into the system. This added protection eliminates the requirement for on site construction personnel to become familiar with the technical details of inputting data to the computer.

While the data input is designed to be batch mode the data output to site can be at least in part interactive. On site personnel requiring certain data (e.g.--materials received, changes approved, etc.) could get an immediate response to their request. Utilization of a smart terminal (one that can store data and release it in bursts) can minimize

on line time to the main central processing unit--a significant feature when many projects are ongoing simultaneously. Printers would be only in the central office and not on site due to the necessity of maintenance of paper and the harsh on site environment. Written reports would therefore be available only on a next day basis.

A small plotter would also be available only in the central office for production of graphs, charts, drawings, etc. The plotter output would be available only on a next day basis.

The capacity of the system installed into the firm should be 50% to 100% greater than the minimum calculated requirements. This is to allow for expansion and also for additional uses of the system which arise only after the system is installed.

Additional expansion capacity can also be achieved by relaxing the implied constraints. Lengthy reports can be printed overnight even when the system is unattended. It may not be necessary to have all files on line simultaneously, etc.

The system must also be modular in function so that it is possible to add compponents or peripherals to the system without any change in the existing hardware or software.

Even with the best of planning introduction of a computer system invariably precipitates changes which eventually manifest themselves in changes to the computer system requirements. Therefore every computer system must be flexible and easily able to accomodate changing needs. This feature must be designed into the computer system from the very beginning.

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GLOSSARY OF COMPUTER TERMS
(Ref:4)

GLOSSARY

The following list of terms used in the computer field is not intended to be exhaustive or definitive. It does, however, include most of the terms of technical significance used in this book, defining these terms here to spare the reader from turning to another source for their meanings. Italicized words within definitions refer to other entries in the glossary.

absolute address: The address of a storage location as recognized by the computer; e.g., pigeonhole 279 rather than the "second one from the corner."

access time: The time between specification of a storage location and access to it for reading or writing; usually shorter than the *storage-cycle* time for computer *main storage*.

address (n): The designation of a storage location, comparable to a house number that identifies a residence; *see also* absolute address, relative address, and symbolic address.

address (v): To refer to a storage location.

alphameric: See alphanumeric.

alphanumeric: The letters of the alphabet, the digits 0 through 9, and certain punctuation marks, for a total of from 48 to 64 discrete symbols, depending upon the system used; *alphameric* is another name for this set of symbols, usually represented in six-bit *BCD* code or eight-bit *EBCDIC* code.

ASCII: American Standards Code for Information Interchange, an approved standard code based on teletype code, but expanded to 7 *bits* per *character*, thus allowing up to 128 discrete characters; an extended version of this code, using 8 bits per character, accommodates 256 discrete characters, like *EBCDIC*, but the code patterns for each character differ from those in EBCDIC.

assembly: The process of translation by the computer of a *symbolic program* into an absolute program which it can execute.

background: The *batch processing* performed by a *time-sharing* system "behind" its *demand processing* load to fill the gaps between demands.

backup: A comparable *hardware* array available in case of failure of on-premises equipment; often arranged on a reciprocal basis among neighboring computer users.

batch processing: Conventional computer usage in which the information to be processed is accumulated outside the computer and then submitted as a batch for most efficient processing (from the computer point of view); contrast with *demand processing;* note that some data are naturally batched, such as periodic payroll data.

BCD: Binary-coded decimal, which see.

benchmark problem: A problem submitted to competing suppliers of processing facilities for a comparative evaluation of their performance of said problem; a standard measurement of the performance of the delivered computer system as compared to supplier's claims.

binary: Literally dual, or two-valued; the binary number system is based on the number 2, just as the decimal number system is based on the number 10; computers use binary numbers internally in one form or another because on-off devices (having the values 1 if "on" or 0 if "off") are used in their construction.

binary-coded decimal (BCD): One form of information representation within a computer, coding (i.e., representing) each decimal digit by 4 binary bits; BCD is extended to include letters of the alphabet and punctuation marks by using two extra *bits*, called *zone bits;* this 6-bit BCD code can represent 64 different symbols (digits, letters, punctuation marks), although some equipment recognizes only 48 of the 6-bit combinations as valid symbols.

bit: Abbreviation of *binary* digit; has either of two values, 1 or 0, as opposed to a decimal digit, which may have any value from 0 through 9; also, the smallest information unit, a "yes" or "no" decision.

block: A group of *records, words,* or *storage* locations, treated as a physical unit; a block on magnetic tape, for example, may contain several logical records, which are combined into the one block for greater efficiency in information transfer.

byte: Generally, any separately manipulatable group of bits within a *binary fixed word,* simplifying the packing and unpacking of these words; more specifically, in a large group of computers, a unit of information 8 bits in length which can represent a *character* (one out of 256) in *EBCDIC,* two decimal digits in *packed format* (4 bits per digit), or any value up to 255 ($2^8 - 1$) in binary form; larger binary values may be represented by groups of bytes.

character: A symbol representable in *BCD* or *EBCDIC* code; usually also a 6-*bit* group that represents one of the 64 possible symbols representable by that many bits or an 8-bit group that represents one of the 256 possible symbols representable by that many bits.

check point: Generally, a point at which a program can be safely interrupted and from which it can be resumed; more specifically, a point within a program preceding an untested portion of the program that may destroy previously developed results of processing.

COBOL: Common business oriented language.

coding: The second phase of programming which turns a machine-executable problem solution into a series of machine instructions to perform that solution.

compatible: One designation of the computers introduced by most manufacturers in the mid-1960s; these computers are distinguished by their grouping into several families, all of whose members can execute the same programs (within certain limits) without program modification; also featured is a combination of *fixed-word* and *variable-word* operations to accommodate both scientific and business data processing.

compiler: One *software* item which directs computer conversion of a

source program in other than symbolic form into either symbolic or executable (e.g., *object program*) form; a source program written in COBOL is converted by a COBOL compiler, a FORTRAN source program is converted by a FORTRAN compiler, and so on; *see also* assembly.

computer: Any device able to accept information and modify or manipulate it to produce meaningful results (*see also* digital computer); in this broad sense, an adding machine is a computer.

CPM: Critical path method, one aspect of *PERT*.

data channel width: In *compatible* computer lines, one of the differences among different models in a single line, describing the amount of information exchanged between *main storage* (or *memory*) and the rest of the computer during any one *access* time to storage; all *variable-word* computers have a data channel width of one *character; fixed-word* computers have a data channel width of one *word; compatible* computer models differ in offering a width of one *byte*, one word (four bytes), or two words (eight bytes).

data processing: A general term for *information* handling, including sorting, classification, recording, calculation, summarization, etc.; commonly restricted to mean either computer or EAM (electric accounting machine) processing of information.

demand processing: Processing of an input or *transaction record* as soon as it becomes available; an airlines reservation system uses demand processing for a minute-by-minute inventory control operation as opposed to an inventory control system that runs only at day's end on the accumulated *batch* to update its master files after all transactions for the day have been completed; sometimes referred to as *real-time, on-line* processing, although real time covers a larger area; also describes multifunction as opposed to dedicated processing systems; for example, a system that processes inventory control, production monitoring, and management information queries intermixed is one form of a demand system, whereas a system that handles only airlines reservations on a "here and now" basis is a dedicated system.

Dennison tickets: See pin-punched tickets.

digital computer: Any device that handles information in the form of discrete numbers (e.g., an adding machine); usually restricted in meaning to high-speed electronic computers which are digital (i.e., count on their fingers) rather than analog (i.e., use a physical quantity like electric current or turns of a wheel to represent other physical quantities).

double word: In a *fixed-word* computer, an information unit twice the length of its *word;* for a *byte*-organized or *compatible* computer, this information unit is 8 bytes (*64 bits*) in length.

dump: A program-testing technique that produces a record of current *memory* contents as an aid in determining what the tested program has done up to the point of the dump.

EBCDIC: Abbreviation for extended *BCD* interchange code; used to describe the 8-bit code (which allows 256 different symbols or *characters* to be represented) used in *compatible* computers.

edit (v): To validate information before it is submitted for processing; to check information submitted to the computer for conformity with prescribed limits (e.g., five-digit account numbers, etc.); to rearrange information within the computer for more comprehensible presentation outside the computer (e.g., introducing spaces between successive fields of a record before printing and suppressing leading [left-hand] zeroes in amount fields).

electromechanical: Using the flow of electricity to control and move mechanical structures such as relays; an electromechanical device is characterized by speeds of hundreds of operations per second in contrast to electronic devices with speeds of millions of operations per second.

electronic: Using vacuum tubes, transistors, or other devices that operate by the flow of electrons at ultrahigh speed; contrasted with *electromechanical*, which see.

E-13B: The type name of the characters accepted by the American Bank Association as standard for their *MICR* encoding on bank checks; the E-13B set includes the digits 0 through 9, a dash, an amount symbol, a transit (clearing house) symbol, and an "on-us" symbol to set off information of use to the issuing bank (such as the account number and branch).

exception handling: The procedures for dealing with unusual or rare items, to avoid degrading system performance on run-of-the-mill items.

exception reporting: A technique for reducing the volume of output from a processing system by reporting only those results that differ from expectations or rules and require management attention or resolution.

executive: The master program which controls the execution of other programs; sometimes used synonymously with *supervisor*.

field: A subdivision of a *record*, containing one item of information; e.g., an employee's weekly time card contains his identification number in one field; related to *variable-word* in some computers.

fixed point arithmetic: Arithmetic operations that assume the position of the decimal point in each number being processed; for example, fixed point operation with dollars and cents assumes that the decimal point is to the right of the rightmost digit, thus treating the amount as all cents (unless more precision is required, as in interest calculations where tenths or hundredths of a cent may be carried); *see* floating point.

fixed word: A form of computer organization in which its storage contains fixed-sized locations (of *word* size) into which information must be fitted; in general, a computer of this type accesses a full word each time it addresses its storage in contrast to a *variable-word* computer, which accepts only one *character* on each (internal) addressing of storage; a fixed-word organized computer is thus often faster than its opposite number, but may lose this speed advantage if the information does not fit neatly into its word size; *see* compatible.

floating point arithmetic: Arithmetic operations that calculate the position of the decimal point in each result; this form of arithmetic frees the programmer of accounting for the decimal point in his program, but takes more time in execution and can lose some precision in its results; it is used most often in scientific and engi-

neering calculations on limited-precision information and in statistical calculations that are concerned with principal values and not refined results; *see* fixed-point.

flow chart: A graphic presentation of the processing steps in an information processing system which is more or less detailed, depending on the scope covered by the chart.

FORTRAN: Formula translator.

gaming theory: A field of mathematics devoted to simple games of strategy in which the opponent's strategy has an appreciable effect (unlike ticktacktoe, in which a defensive player can always force a draw); sometimes applied to evaluation of sales campaigns in a competitive environment.

half-word: In a *fixed-word* computer, an information unit one-half the length of its *word;* in a *byte*-organized or *compatible* computer, an information unit 2 bytes (16 *bits*) in length.

hardware: The actual equipment making up a computer or EAM system; contrast with *software.*

header card: The first card in a multiple-card record on punched cards; the header card contains the record identification and other information as well; *see* trailer card.

imprinter: A device for adding some printing to an already-printed document; e.g., the gadget that prints from your credit card onto the charge card.

instruction: A direction to the computer to perform one of its basic operations, such as ADD; each instruction calls for the performance of only one operation; *see also* instruction list.

instruction list: The complete repertory of basic operations that the computer can perform, ranging from 40 to over 100 in different computers; each instruction in the list is uniquely identified by its instruction code; a single program will not necessarily use every instruction in the computer list, but it will use those needed to perform the required operations in the appropriate order and as often as needed to accomplish the program objective.

I/O: Abbreviation for input/output, referring to the array of devices through which information is entered into or put out by a computer.

Kimball tickets: See pin-punched tickets.

line printer: An *I/O* device that produces readable copy at high speeds (e.g., 150 to 1500 lines per minute).

linear programming: A field of mathematics that deals with simple (i.e., linear), sometimes numerous, relations that can be evaluated by a computer; one form of *modeling* or *simulation.*

logic: As used in the computer field, the system that relates the input signals to a computer component with its output; more broadly, within the computer field, the rigorous application of reason to a problem.

magnetic-card array: A *random access* device that features higher capacity than disc or drum, but which has longer access times; various trade names for this type of device are Data Cell, CRAM, etc.

magnetic disc: A storage device that uses the surfaces of one or more discs for magnetic recording; each surface is divided into *tracks,* which are further divided into *sectors.*

main storage: Computer *memory.*

management by exception: See exception reporting.

management information system: The adaptation or overlay of an information processing system to provide management with the information and control it needs over the area covered by the system; a good computer data processing system includes the elements of a management information system without becoming overbalanced in that direction.

mark sensing: A machine-readable medium that recognizes special pencil marking in particular areas on a form; one example of mark-sense forms is the multitude of machine-markable or gradable multiple-choice test forms.

master file: The collection of records that changes slowly (if at all) with time, and against which *transaction records* are processed; for example, a payroll master file contains a record for each employee, containing his pay rate, Social Security number, number of deductions, withholding obligations (hospitalization insurance, payroll savings, union dues, etc.), address, and so on; the master file may also carry accumulations of previous transactions such as gross earnings to date, amounts withheld for taxes, vacation time accrued, and so on.

memory: Storage section of computer, holding program(s), data, and results.

MICR: Magnetic-ink character recognition, a generic name for machine-readable records that are also human-readable, using magnetizable ink for machine recognition; the most widespread use of MICR in the United States is on bank checks; *see* E-13B.

mnemonic: Literally, easy to remember; more specifically, the abbreviations or code symbols used in symbolic programming languages to designate the various machine instructions; also applied to the symbols or names of locations if these are designed to be understandable as abbreviations.

modeling: The use of a computer to imitate some process or situation represented by a set of mathematical relations that constitute a model of the process or situation; *see* simulation.

monitor: See supervisor.

multiprogramming: The execution of two or more programs within a single, extended time interval, allowing each program to proceed when its requirements (e.g., I/O transfers) are met, but allowing the other program(s) to proceed while the first awaits some requirement.

object program: The result of computer conversion of a *source program;* unless errors have been found, the object program can be executed by the computer.

OCR: Optical character recognition; machine-readable records that depend on character shape rather than magnetic properties of the ink in which they are printed (but *see* MICR); used for gasoline credit cards, on some cash registers, and by the New York State Bureau of Motor Vehicles on registration forms.

off-line: Not directly connected to the computer; in the context of data

communications, not directly connected to the transmission line as in keyboarding information onto perforated tape *off-line* for later *on-line* transmission at higher-than-keyboard speed.

on-line: Directly connected to the computer; the significance of this term depends upon your point of view, whether from inside or outside the computer; for example, a line printer can be fed directly from the computer, putting it on-line to the computer, or the computer can put out its records for printing onto magnetic tape (which is then read through another computer to its printer), putting the printer *off-line* to the first computer; conversely, an airlines reservations clerk is on-line to his computer because he enters a request for information that is answered directly by the computer; the clerk's impression is quite correct from his point of view even though his request is accumulated outside the computer before it is entered, and the computer services that request when it gets to it; this occurs many operations later, by computer time, but almost instantaneously in the clerk's reference frame.

operand: The item operated on by an instruction; the operands of an ADD instruction are the two numbers to be added.

operating system: A utility program system that schedules the operation of a computer in executing *batch processing* for maximum computer utilization; similar to a *supervisor*, although the operating system may not handle all input/output operations for application programs.

operations research: A field of applied mathematics devoted to the development of mathematical models of real situations or processes, said models being manipulatable by computer to reveal the relations among the controlled and uncontrolled variables in the model; the model may be simplified with respect to the real world, for ease in manipulation; its validity must always temper the acceptance of conclusions drawn from its performance.

packed format: Decimal numbers in *BCD* (or *EBCDIC*) which have had their *zone bits* removed from all but one digit; a packed decimal number takes less storage space than an *unpacked* decimal number, four bits per digit as compared with six (or eight in EBCDIC); also the storage of two (or more) information items in one *word*.

paper tape: One form of *perforated tape*; other forms use metal foil, polyester bases (e.g., Mylar), and sandwiches of these materials.

perforated tape: A recording medium like punched cards, but not restricted to 80-character records; often produced as a by-product of keyboarding on a properly equipped typewriter or a teletype unit.

PERT: Program evaluation and review technique.

pin-punched tickets: Small tags with small holes that code the merchandise characteristics; used for inventory control or sales analysis of clothing items by department stores; often described as *Kimball* or *Dennison* tags, after two competing suppliers.

problem definition: The first phase of computer programming, reducing the problem to a form that allows machine solution; *see* systems analysis, coding.

problem-oriented language: A computer programming language that uses the terminology "natural" to the problem area rather than to the computer to be used; such languages are usually also machine-independent; examples include COBOL, PL/I, etc.

procedure-oriented language: Similar to *problem-oriented language* but often more general in application; for example, FORTRAN is a procedure-oriented language, accommodating common mathematical expressions with little or no change.

process control: The application of a computer to a continuously changing situation (e.g., oil refinery, power distribution network, etc.) to control and maintain optimum performance of the controlled system; a truly *real-time* system that demands most of the computer capabilities just to keep up with the control system.

program (n): The sequence of *instructions* that directs a computer in its performance in solving a problem.

program (v): To prepare the sequence of instructions for a computer; usually divided into two phases, the first being problem definition (or *systems analysis*) and the second being *coding*.

punched card: A machine-readable medium commonly used in EAM and in computer systems; each punched card can hold 80 (or 90 in some designs) characters in *BCD* code; the punched card is one of the cheapest mediums of storage and one of the most widely used.

query-response system: One form of *demand processing* in which the user operates in *real* (to him) *time* with the computer; this form of processing gives each user the sense of being master of the computer, whereas it is actually serving all masters and, possibly, doing a good bit of *batch processing* on the side (in the *background*); some *process control* systems (notably those for air traffic or air defense) include a query-response subsystem to service their human masters while they spend the bulk of their (high-speed) time maintaining the picture of things as they were an instant ago, said picture being the source of answers to the human queries; not all query-response systems include a process control system (e.g., airlines reservations) unless the source of answers changes at a high (to the computer) rate.

random access: A storage medium characteristic, indicating that records are available (more or less) independently of their location in the storage medium; computer *main storage* (magnetic cores) is fully random access, whereas other storage media only approximate this randomness or independence of location; contrasted to *sequential access*; examples of random access media include magnetic drums, magnetic discs, magnetic-card arrays, etc.

real time: Most generally, "here and now" time, by the clock rather than by some arbitrary time scale; a system that only keeps up with its human user is often called a "real-time system," whereas the term is better applied to a system that devotes most of its activities to keeping current with a constantly changing situation; *see* process control.

record: A group of related information items treated as a logical unit; usually, a record is divided into one or more *fields*, each containing a different subitem of information.

relative address: The designation of a storage location, in symbolic

programming, by indicating how far it is from another location; i.e., relative to that other location.

run (n): A complete sequence of processing by a computer on one submission of input data, requiring little or no operator action after he sets it up; usually limited in its processing capability by the number of I/O devices on the computer and by the computer storage size.

run (v): To execute a program or a complete subportion of a program on a computer.

sector: A portion of a *track* on a *magnetic disc* surface, usually a separately addressable portion.

sequential access: A storage medium characteristic, indicating that records are available sequentially (one after the other) in some fixed order; contrasted to *random access;* examples of sequential access media include punched cards, perforated tape, magnetic tape, etc.

significance coding: Assignment of identification codes with inherent *meaning* to *items* identified; for example, Selective Service numbers identify the draft board, the date of issue, and the individual in question; contrasted with arbitrary coding in which the identification codes have no meaning.

simulation: A technique of computer usage that employs the computer as an imitator or modeler of some other situation or process to obtain, inexpensively, some indication of results from the simulated situation or process.

software: The set of programs used with a computer to write other programs, perform standard operations, or to make the computer appear to be another machine; often extended to include the applications programs (problem solving) run on the *hardware* and *software* combination.

sorting: The process of placing items in order on some key (e.g., account number or inventory description number).

source program: A program written in symbolic or other nonexecutable form (e.g., COBOL, FORTRAN) and submitted for computer conversion into executable form: *see* object program.

storage: Any medium in which information can be held; written documents, recordings of dictation, punched cards, magnetic tape, etc., all constitute forms of storage; in connection with a computer, *storage* normally refers to the computer main *memory,* usually magnetic cores.

storage cycle: The time taken to read a main storage location in the computer and to write its contents back into the same location; also the time between successive accesses to the same storage array; sometimes referred to as the computer's *unit-time interval;* this time is generally longer than the *access time* for the main storage.

stored program: Characteristic of a computer that retains its *program* internally, allowing it to modify its program in response to the results of its calculations; contrasted with fixed or externally programmed devices, neither of which allows program modification in the same way.

subsystem: An isolable portion of a system, a subsystem is treated as a complete system while its interactions with other elements of the larger system to which it belongs are ignored.

supervisor: A program that controls computer input/output operations and acts as traffic clerk for all computer operations, including scheduling of application program execution; most *compatible* computers require a supervisor program for efficient use of the computer; *see also* operating system.

symbolic address: The address of a storage location designated by an arbitrary name or label rather than as an *absolute address.*

symbolic programming: A machine-oriented programming system that relegates to the computer much of the bookkeeping involved in producing an executable program; this form of coding uses *mnemonics* to designate machine instructions, *symbols* or labels to name or identify storage locations, and *relative addresses* rather than *absolute addresses;* a symbolic program must be translated with an *assembly* program by the computer before it can be executed.

system: An organized whole; the complete assemblage of personnel, equipment, and procedures which accomplishes an overall purpose; the organization of a system may be inherent in it or imposed from outside.

systems analysis: The examination of a procedure or a segment of business operation to determine its requirements and the best means of accomplishing them; usually, but not necessarily, the examination considers the best means for computer accomplishment.

time broker: A dealer in computer time, selling at retail to prospective users or simply matching prospective users with potential time sellers in return for a commission.

time sharing: Generally, the use of a computer for more than one application at a time by allocating successive time slots to active applications; a more restrictive sense of this phrase describes multiple-user access to a computer in "real-to-each-user time"; in this sense, an airlines reservation system is a time-sharing system.

total system: A philosophy of computer application that integrates all information processing within an area (or a company) for processing by the computer, minimizing clerical operations and human activities in the area.

trace: A program-testing technique that records selected storage locations before and after execution of the program instructions being traced, producing a dynamic record of that portion of program results.

track: The area swept on a magnetic recording device by a read-write head.

trailer card: The second and succeeding card(s) in a multiple-card record on punched cards; each trailer card carries some identification to associate it with its record and to indicate its position in the sequence of cards carrying that record; also, the trailer card carries additional information for that record; *see* header card.

transaction record: A record of data to be entered against a *master file* record; a weekly time card, a charge-out from inventory, a record of receipt of ordered goods, a request for a seat on a given airline flight—all are transaction records.

transfer rate: The rate in characters or bytes per second at which information can be moved into or out of a storage medium; the transfer rate for computer main storage is the reciprocal of its storage

cycle and is thus related to its *access time*; for other *random access* storage devices, the transfer rate is not related to the access time.

turnaround technique: The use of a computer-originated document as input to a later computer run; e.g., the payment stub on a credit card or utilities bill.

turnaround time: The elapsed time between submission of data and program to a computer and the return of processed data; this time can run from 24 to 48 hours in a large *batch processing* system.

unit-time interval: The minimum time between successive accesses to computer main storage, either to obtain an *instruction* or an *operand* (i.e., an information unit to be processed).

unpacked format: Decimal numbers in *BCD* (or *EBCDIC*) with their *zone bits* present; i.e., all six (or eight) bits populated.

utilization factor: The ratio of computer time used to computer time available; a measure of machine employment but not of system efficiency.

variable word: A form of computer organization in which bit storage contains locations of *character-size* which can be designated as part of a variable-size *word* or *field*; no storage space is wasted on undersized information units (undersized in comparison to a fixed word, that is), but the computer accesses only one character at a time from storage, using several storage cycles to process a single word even though the programmer *addresses* the word, not its individual characters; *see* fixed word.

verification: A checking operation following the punching of punched cards to determine that the correct information has been punched; the verification operator keys in the same information that was used to punch the cards, and this is compared with what is punched in the cards, to determine any differences or possible errors.

word: A larger information unit than the *character* (6 bits) or *byte* (8 bits); formed on the analogy that several characters in English make up a word; sometimes used interchangeably with *field*; in *byte-organized* computers, a *word* contains 4 bytes (32 bits).

zone bits: The added bits (two or four) that add the capability of representing letters to the decimal-digit representation possible with four-bit *BCD* codes; sometimes used to represent the sign (+ or −) of a decimal number in *BCD*.