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UTILIZATION OF MICROCOMPUTERS IN THE CONSTRUCTION INDUSTRY

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UTILIZATION OF MICROCOMPUTERS
IN
THE CONSTRUCTION INDUSTRY

BY

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ABSTRACT

The use of computers in the construction industry is increasing but the extent and the rate of the growth is minimal considering the availability of this technology. In an effort to determine the extent to which computers are utilized in the construction industry, a survey was conducted among construction contractors in Atlantic Canada.

Construction contractors responding to the 1985 computer utilization questionnaire who were using computers indicated that they were generally well satisfied with commercially available software that perform general accounting functions, such as, accounts payable/receivable, job cost, general ledger, and payroll. Most were not, however, utilizing their computers for tasks that require a great degree of user programming skill. Nor were they using the commercially available software outside the accounting area because of the non-compatibility of the software with their in-house procedures.

Among the contractors who did not use computers, it was found that the non-use of computers was mainly due to the contractor's lack of knowledge of computer systems, both hardware and software. There was also a general misconception about the high cost of computerization.

In order to expand the use of computers in the construction industry, a data processing system has been developed, which is expected to solve many of the problems of extending computer use outside the traditional accounting areas. The suggested system makes use of an integrated software package developed for the microcomputer. Integrated software packages offer computer capability with a minimum amount of effort on the part of the users. The data processing system is demonstrated by modelling real life construction related tasks such as specifications, estimating, forecasting, design, bidding, cash flow analysis, project control, equipment replacement, and owning & operating cost calculations.

To facilitate increased use of computer technology in the construction industry, criteria for the selection of computer systems are presented. The criteria describe the characteristics of and selection procedures for both hardware and software commonly used in the construction industry. The criteria also outline the pre-implementation procedures and make specific recommendations for computerization.

It is expected that the suggested data processing system and the guidelines for the selection of a microprocessor-based computer system will enhance computer utilization in the construction industry, especially in small construction firms.

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Chapter 1
PROBLEM DEFINITION

1.1. INTRODUCTION

Computing systems for construction applications have been commercially available for many years. The introduction of inexpensive microprocessor-based computer systems has given construction contractors new tools and procedures for manipulating, storing and retrieving timely information. Computer software programs to perform a wide range of accounting, scheduling, and estimating tasks are now available for the construction industry. Also, there is a growing realization among the construction contractors that computers are general tools for making better bids, managing jobs more profitably, performing sensitivity analysis on decisions made under uncertainty, and controlling costs more effectively.

With this growing realization of computer use and the availability of inexpensive microprocessor-based computer systems, one would think construction contractors would be utilizing computers to the fullest possible extent. An effort was made to determine the extent to which the computers are utilized in the construction industry [8]. A comprehensive questionnaire (Appendix A) was developed and mailed, in February 1985, to five hundred and forty construction contractors throughout the Atlantic Canada. Of the two hundred and two contractors who responded to the questionnaire, 40% were utilizing the computers for their data processing needs; 60% of the contractors indicated that they did not use a computer in any manner.

The survey revealed two problems in the use of computers in the construction industry. Firstly, the contractors who were using computers were utilizing them for general accounting and bookkeeping functions only. Secondly, a vast majority were not using the computers at all. This survey therefore was the basis for defining the problems of partial use and the lack of computers' use in the construction industry. This therefore, set the stage for research work on the development of a user-oriented data processing system, and the procedures and guidelines for the selection of computer systems.

This chapter describes the computer utilization survey and its results leading towards the identification of the problem. Based on this analysis objectives of the research study are outlined and methodology for research is presented. This chapter is organized under the following major headings:-

1. Computer utilization survey
2. Analysis of the survey and problem identification
3. Objectives of the study
4. Methodology

1.2. COMPUTER UTILIZATION SURVEY

The objective of the computer utilization survey was to find the extent of computer utilization and the causes of resistance to computer use among construction contractors. The questionnaire (Appendix 1) sought information on the size of contractor's firm based on annual contract volume and number of T4 forms processed, the type of computer system or service bureau being used and the type of data processing applications done by computers. The questionnaire also asked the contractors to rate the commercially available software currently used by their firm, and to identify the benefits associated with computer use. One of the main objectives of the survey was to explore the causes of resistance towards computer use. In the following subsections, the results of the survey are discussed in detail.

1.2.1. Response to the Survey

Five hundred and forty questionnaire forms were mailed to construction contractors selected from the mailing lists of contractors associations of Atlantic Canada. Out of five hundred and forty contractors, two hundred and two (38%) completed and returned the questionnaire survey form. The distribution of these two hundred and two contractors with respect to their construction speciality is illustrated in Figure 1-1. Roofing, masonry, structural, concrete, site work, civil, industrial installation, and renovation contractors are grouped as speciality/trade contractors. Consultants, control systems, surveying, testing, inspection, and marine construction contractors are grouped as miscellaneous contractors. The rest of the classifications in Figure 1-1 are self-explanatory. An encouraging

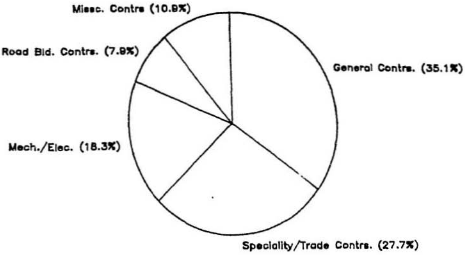


Figure 1-1: Distribution of Contractors by Construction Classes

response to the survey indicated a general interest among contractors in computerization of their data processing needs. In fact, all contractors expressed a desire to obtain the results of this survey and guidelines for selection of computer systems, which were promised in the questionnaire.

1.2.2. Computer Utilization Trends

Two hundred and two responses were received from the questionnaire survey. A general distribution of the questionnaire responses is shown in Figure 1-2. Three contractors had both micro and minicomputers. Eight contractors used both in-house computers and service bureaus. Three out of six mainframe users mentioned that they did not own an in-house computer as such, but enjoyed the computer facilities of their parent organizations.

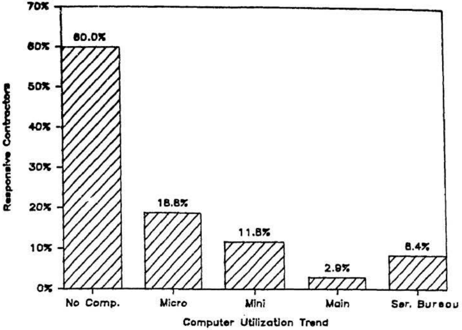


Figure 1-2: Data Processing Modes Used by Contractors

It should be noted that the contractors participating in the survey were selected from contractors' associations mailing lists of Atlantic Canada. Responses were therefore received from a high percentage of small general and specialty contractors. For small contractors, the annual contract volume alone is not a good indicator for determining the size of the contractor's organization. Emphasis was therefore also given in the questionnaire to determine the number of T4 forms processed per annum by each contractor. Annual contract volume together with T4 forms processed per annum would be a more reliable indicator of the size and scale of activity of the contractors and their volume of actual data processing requirements.

The range of annual contract volume and the number of T4 forms processed per annum by responding contractors were $0.1 million to $55 million and 1 to 1,000 respectively. The distribution of computer classification as a function of annual contract volume and T4 forms processed per annum is given in Table 1-1.

DATA PROCESSING MODES	ANNUAL CONTRACT VOLUME (in million of $)				ANNUAL T4 FORMS PROCESSED			
	MAXIMUM	MINIMUM	AVERAGE	MAJORITY	MAXIMUM	MINIMUM	AVERAGE	MAJORITY
No Computer	$8.0	$0.1	$2.8	$0.1-$5	120	1	45	1- 70
Microcomputer	$12.0	$0.1	$5.4	$0.1-$8	200	10	104	1-140
Minicomputer	$30.0	$7	$14	$10 -$20	450	30	187	100-265
Mainframe	$55.0	$25	-	-	-	-	-	-
Service Bur.	$20.0	$0.1	$6.8	$4-$9	350	20	166	40-168

Table 1-1: Computer Classification as a Function of Annual Contract Volume and T4 Forms Processed

It can be seen from the Table 1-1 that contractors with contract volumes between $0.1 million to $10 million were mostly using the microcomputers and the contractors with annual contract volumes in excess of $10 million had chosen the minicomputers for their data processing needs.

1.2.3. Computer Acquisition Trends

As the hardware and software problems are diminishing and the costs are declining, computer usage in construction industry is spreading even among the small construction organizations. This is mainly due to the growing popularity of microcomputers in the construction industry. This fact is substantiated by the survey results. The survey results indicated that twenty five of the eighty contractors (32%) had purchased their computers since January, 1985. Out of these twenty five contractors twenty two had purchased microcomputers. The trend in computer acquisition by the responsive contractors is shown in Figure 1-3. For the most part, there was an increasing trend for the computers purchase from 1979 to 1985 with the exception of 1984, when the purchase declined because of economic recession.

In 1984, six out of twelve contractors purchased microcomputers, four minicomputers, and one a mainframe computer. In 1983, construction contractors purchased nine microcomputers, five minicomputers, and two mainframe computers. The comparison of the purchase of mainframe computers in 1983, 1984, and 1985 indicated that the purchase of mainframe computers was maximum in 1983 and none so far in 1985. This is because the medium and large size contractors had started using microcomputers in addition to mainframe and minicomputers.

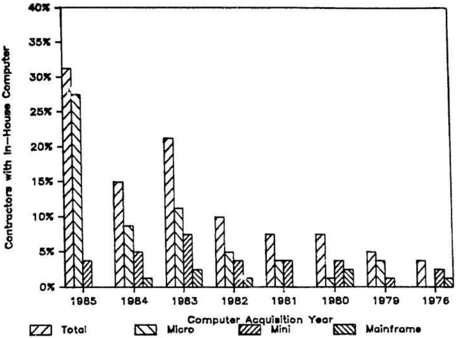


Figure 1-3: Computer Acquisition Trends

1.2.4. <u>Hardware Preferences</u>

Several hardware trends, with varying computing power, storage, and operating systems, were reported by the contractors participating in the survey. The most popular microcomputers reported by the contractors were the IBM PC and IBM System 23. Most users were using those computers with 60 K RAM and 2 or 3 optional floppy disk drive units or hard disks. The use of a wide varity of printers and plotters were also reported. EPSON MX80, 160 CPS dot matrix printer were the most widely used. Other popular microcomputers included the Wang PC and Apple II.

The most popular minicomputer reported by the survey was the IBM System 36, with 256 K RAM and a 180 CPS printer.

IBM and Apple hardware were apparently popular with Atlantic Canadian construction firms. This was because of the availability of pre-written application software compatible with these vendors' products.

1.2.5. Time and Cost Savings Experienced by Contractors

The questionnaire was also designed to obtain descriptive material about the time and/or cost savings experienced by the contractors as a result of computer use. Many contractors who responded to the questions indicated a time savings of 20 to 50%, depending on the type of work performed. A time saving of four days per month on payroll, three days per month on general ledger and accounts payable/receivable, 30 to 50% time saving in estimating, and flexibility in scheduling jobs were reported. However, most of the responsive contractors agreed that dollar savings could not be determined directly. A few medium size contractors experienced a reduction of half of the accounting staff due to computer use. The result was not the same for the small size contractors, because in these organizations a minimum basic staff is required with or without computers.

Contractors who responded to the survey and who were utilizing the computer, agreed that with the use of computers, reports could be processed more accurately and in a timely manner, which alone justified the purchase of the computers.

1.2.6. Application Software Ratings

A wide variety of software for the construction industry has been developed for use in all types of computers. A considerable part of the questionnaire was directed towards investigating the extent of application software utilization in the construction industry. Forty six of the eighty contractors (58%), who reported owning their own computer, had purchased or obtained by lease, comprehensive accounting software packages developed by software vendors specifically for the construction industry. Generally, this type of accounting software consists of four or more integrated modules or programs that perform the basic accounting functions.

Practically all microcomputer users participating in the survey purchased their software from independant third party vendors. The cost of such software ranged from $400 to $3,500 per module with some vendors charging extra for training and support. In most cases, minicomputer users reported purchasing their software and hardware at the same time in one "turnkey" package. Under the turnkey arrangement, a single vendor sells, services, updates and supports the entire hardware/software system.

The contractors participating in the survey were also asked to rate subjectively the application software programs which were in their use. A summary of their ratings is shown in Table 1-2. It is somewhat surprising to see that 58% of the contractors were utilizing their computers for accounting functions (Accounts Payable/Receivable, General Ledger, Project Cost Accounting, and Payroll) and only 28% were using them for estimating, 8% were using them for project scheduling, and 20% were utilizing them for equipment accounting. The benefits of the use of the computers for CAD and drafting had not yet been recognized by the construction contractors. The lack of computer use in areas other than accounting and bookkeeping was reported to be mainly because of the non-compatibility of the commercially available software.

A wide variety of software was reported in the survey. For word processing the "Wordstar" microcomputer software package was found popular among Atlantic Canadian construction firms. Five contractors were using electronic spreadsheets or integrated packages for estimating application. These contractors were quite satisfied with the performance of these packages in estimating. The popular electronic spreadsheets and integrated packages reported in the survey were Lotus 123, Multiplan, and VisiCalc. Seven contractors using commercially available software packages for estimating said, that these software packages to some extent were not compatible with their in-house procedures.

For the most part, both mini and microcomputer users were quite satisfied with the software packages that perform accounting functions. Most of the contractors were critical of the constraint on flexibility and non- compatibility to in-house procedures of the pre-written application software packages.

Software Package	Percentage of Contractors Utilizing the Module	Ratings of Contractors Utilizing Commercially Prepared Software Package*																								
		General Contr.					Mech./Elec. Contr.					Speciality Trade Contr.					Road Building Contr.					Misc. Contr.				
		E	G	A	P	N	E	G	A	P	N	E	G	A	P	N	E	G	A	P	N	E	G	A	P	N
Accounts Payable/Receivable	60%	** 17	40	8	3	32	29	35	6	0	29	5	30	15	15	45	25	38	13	0	25	0	11	11	0	78
General Ledger	58%	17	30	22	0	31	29	29	6	0	35	10	30	0	10	50	15	25	35	0	25	11	11	11	0	67
Project Cost Acc.	58%	20	11	18	6	45	24	18	6	0	53	10	10	20	15	45	10	20	27	13	30	1	11	11	11	67
Payroll	56%	11	26	16	3	44	35	24	6	0	35	5	25	20	10	40	38	13	13	10	28	11	11	11	0	67
Word Processing	29%	4	24	4	8	60	0	12	6	0	82	5	5	10	5	75	0	13	13	0	75	11	11	11	0	67
Estimating	28%	3	12	10	16	59	6	10	26	0	58	0	5	5	15	80	0	3	10	13	75	1	11	11	11	67
Equipment Accounting	20%	0	9	8	5	78	0	0	0	0	100	0	3	2	6	89	0	15	10	15	60	0	8	2	0	90
Scheduling	8%	0	4	4	0	92	0	0	0	0	100	0	0	5	5	90	0	15	10	0	75	0	11	11	0	78
CAD & Drafting	3%	0	4	0	0	96	0	10	0	0	90	0	5	0	0	95	0	0	0	0	100	0	0	0	0	100

* Also includes Software Package written by in-house personnel
** All these values are percentages

E - Excellent
G - Good
A - Acceptable
P - Poor
N - Not Using the Module

Table 1-2: Application Software Ratings by Contractors With In-House Computers

1.2.7. Trends in Service Bureaus' Utilization

Service bureaus or consulting services are the organizations which allow contractors to computerize selected aspects of their business operations at substantially reduced financial risk. Seventeen of the eighty contractors (21%) participating in the survey were using service bureaus for their specific data processing needs.

There are many input and output procedures available for using the service bureaus. The input media could be terminal, punched cards, and or mailed data, and output media could be CRT, printer, plotter, and printed reports. Eighty percent of the contractors utilizing the service bureaus used mailed data as the input media and printed reports as the output media. The average time for processing was reported to be two days per week.

The contractors utilizing the service bureaus were also asked to subjectively rate the performance of the service bureaus for their specific data processing tasks. A summary of their rating is shown in Table 1-3.

Most of the contractors utilizing the facilities of service bureaus said that because of the decreasing prices in hardware and software, they planned to purchase their own computer and stop using the service bureaus. Four of the seventeen contractors using in-house computers in addition to a service bureau planned to drop the service bureau as soon as they became familiar with their own computer.

Software Module	Percentage of Contractors Utilizing the Service Bureaus for Module	Ratings of Contractors Utilizing the Service Bureaus			
		Excellent	Good	Acceptable	Poor
General Ledger	70.5%	25%	42%	23%	10%
Project Cost Acc.	58.8%	30%	40%	22%	8%
Payroll	53.0%	23%	56%	21%	-
Accounts Payable/Receivable	47.0%	12%	50%	13%	25%
Scheduling	42.4%	26%	44%	21%	9%
Word Processing	12.0%	12%	80%	8%	-
Estimating	0.0%	-	-	-	-
CAD & Drafting	0.0%	-	-	-	-

Table 1-3: Service Bureau Performance Ratings by Contractors

Because of the availability of low cost microcomputers, it appears that the service bureau options are losing their popularity. Another reason is that contractors cannot afford the processing time required by a service bureau.

1.2.8. Resistance to Computer Use

Of the two hundred and two contractors that responded to the survey, one hundred and twenty-two (60%) indicated that they did not have or use a computer in any manner. The annual contract volume of these contractors ranged from $100,000 to $8 million.

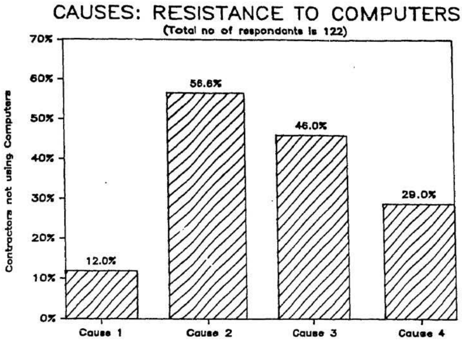
One aspect of the survey was directed to inquire into the reasons of resistance to computer use by the construction contractors. Four specific reasons were therefore mentioned in the questionnaire for evaluation. The response is illustrated in Figure 1-4. Fifteen out of one hundred and twenty two contractors (12%) considered computers and/or service bureaus to be too expensive. Sixty nine (56.6%) contractors said that their company volume did not justify the expense of computerization. The total contract volume during the fiscal year of 1984 for these sixty nine contractors varied from $100,000 to $5 million. Fifty six (46%) contrators suspected that commercially available application software were not compatible with their in-house procedures. Most of these contractors mentioned that since they were small sized contractors and their employees were not exposed to computer data processing , they could not afford experimentation. Thirty five (29%) contractors expressed a desire to know more about hardware and software applicable to the requirements of the construction industry; specifically for estimating, scheduling, equipment accounting, and payroll.

It was found in the survey that many contractors having an annual contract volume the same as for non users (i.e $100,000 to $8 million) were successfully utilizing computer systems. Fifteen of these contractors were therefore contacted by telephone for a personal interview. These contractors, most of them using micro and mini computers were asked the following questions:-

1. Disregarding the initial cost, would you go back to manual bookkeeping ?

2. Do computers save your company any money ?

3. Does the computer purchase justify its expenses ?



Cause 1: Computer and/or services are too expensive

Cause 2: Company volume does not justify the expense of computerization.

Cause 3: Commercially available software are not compatible with in-house procedures.

Cause 4: Need additional information before deciding which computers and/or services would be appropriate.

Figure 1-4: Causes Resistance to Computer Use

None of these contractors wanted to go back to manual bookkeeping. The reason was obvious: they became accustomed to the comfort that computers offered them. All fifteen contractors said that it was difficult to quantify in terms of money savings. Ten said there were indirect benefits, such as the accuracy of the information available and the speed at which the files could be viewed when making management decisions. In response to third question, they all agreed that with the growth of contract volume and the organization, the computer possession allow them to process data in an accurate and timely manner without hiring any additional employees. This fact alone justified even more the purchase of a computer to them. In general, all fifteen contractors were satisfied with the purchase of the computer.

Based on these personal interviews with the contractors, it can be said that the contractors with annual contract volume between $100,000 to $8 million who were not utilizing computers in any manner were not afraid of computer prices but they were reluctant to purchase a computer because their employees had no exposure to computer data processing.

1.3. ANALYSIS OF THE SURVEY

The contractors responding to the survey can be classified into two categories in terms of the use of computers by them. Firstly, the contractors who are utilizing the computer for their data processing needs, and the other, who are not utilizing the computers at all. The survey results are analyzed for both groups and the significant findings are listed below:

The following observations were made about the contractors who are utilizing computers:-

1. The use of microcomputer is increasing in the construction industry.

2. The majority of the contractors, with in-house computers, are utilizing the computers only for traditional accounting and bookkeeping functions despite the fact that computers can be used in many other areas of construction management.

3. The partial use of computers is due to the contractors' apprehension about the need for specialized computer programmers or operators for computer use in areas, such as estimating, scheduling, equipment accounting etc.

4. The non-compatibility of commercially available software with in-house procedures of the contractors is also among the factors contributing to their not extending computers' use outside the accounting and bookkeeping areas.

5. The contractors are reluctant to write computer programs to suit their in house procedures because of the lack of knowledge of the computer programming languages.

The following are the causes of resistance to computer use among the non-users:-

1. A large number of contractors with an annual contract volume of $6 million or less are reluctant to purchase a computer because they are uncertain of the process by which the computer system (hardware/software) should be selected.

2. Most of these contractors, being small, feel that their annual contract volume does not justify computer purchase.

3. Most of the non-users feel that the commercially available software are not compatible with their in-house procedures, therefore, they do not want to experiment with a computer.

4. Fear of hiring specialized computer programmers, operators, or system analysts for implementing the computer system in the organization also exists among the non-users.

5. Most of the non-users of the computers see the applications of computers only for accounting functions, which alone does not justify a purchase to them.

Similar observations were made in a special computer report [38] published in ENR in May 1985 issue. The report mentioned that although a variety of microcomputer software are available specifically for the construction industry, the biggest problem, in most cases, is that these software are not flexible enough to meet the requirements of the contractors' in-house procedures. A study [5] carried out in the USA in 1984 indicated the general reluctance of construction contractors to use their computers for tasks outside the traditional accounting and bookkeeping areas. This was mainly due to the lack of a flexibility and a user friendliness of the commercially available application software. A non-profit centre, with a grant of $2.4 million, to help implement computer technology in the construction industry was established in 1984 at Concordia University, Montreal. The resultant report [9] mentioned that most of the existing software packages for the construction industry must be refined for individual or local needs of the contractors.

Based on the computer utilization survey results and the problems identified in the above mentioned studies, objectives of the research are defined as below.

1.4. OBJECTIVES OF THE RESEARCH

Objectives of the research are two fold:-

1. To provide construction contractors with a data processing system with the following capabilities:-
   a. The system should be compatible with contractors' in-house procedures.
   b. The system should be "User-Oriented" and not require any computer programming languages skills by the user.
   c. The system should not require any programmers, operators, or system analysts to operate it.
   d. The system should be compatible with the microcomputer because of its growing popularity in the construction industry.
   e. The system should be demonstrated by modelling the commonly used construction management functions.
2. To define the criteria for the selection of a complete computer system (hardware/software) for construction contractors with little or no experience in computer data processing.

The methodology of the research in order to meet these objectives is described in the following section.

1.5. METHODOLOGY

Most of the contractors are not utilizing their computers for tasks that require a great degree of user programming skill. Non-compatibility of the commercially available software with their in-house procedures is also among the factors which prevents the extension of computer use outside the traditional accounting areas. To solve these problems of non-compatibility and the lack of flexibility of commercially available software, contractors have to write their own computer programs to suit their in-house procedures. Yet small business owners do not have the time to learn programming languages nor can they pay highly skilled programmers to develop custom application software. Small computer users will, therefore, greatly benefit from some type of general software packages that can be used by non-programmers to solve a wide range of data processing tasks. Fortunately, software packages with these exact capabilities have been made available to microcomputer users in the last few years. They are called integrated software packages and they are marketed under trademark names such as Lotus 1-2-3, Open Access, Symphony, Extended VisiCalc, etc. [17]. These integrated packages are premier examples of user friendly software developed for the personal computer which enable a computer novice to easily, quickly and productively use the computer.

Since their introduction in 1983, integrated packages have been advertised for use primarily as financial planning and analysis tools [21]. Their effectiveness and power as such modelling media have often been demonstrated; however, very little work has been reported in the area of using the integrated packages for construction management purposes.

Williams, 1984 [39] demonstrated the use of the VisiCalc by solving a simple problem of personal income tax calculation. Suckarieh, 1984 [35] outlined a procedure for estimating construction costs. He provided a sample sheet for quantity take-off and recapitulation. However, this study is not a complete demonstration on the subject. Adams, et-al, 1984 [1] subjectively described the use of general application software packages for project management purposes.

Although, these authors indicated that integrated packages may be of great use for project management, detailed applications in project management were not discussed. Rounds, 1984 [33] demonstrated the use of an integrated package for construction cost estimating. He presented a blank quantity survey, pricing, and recap templates. This study also did not provide adequate details of the subject matter. Morse and Whithouse in their two part series, 1985 [24,25], outlined some specific features for the selection of electronic spreadsheet by industrial engineers. Masri, et-al, 1985 [21] described a model that facilitates the use of an electronic spreadsheet for analyzing the flow of work in process through manufacturing systems. They found that the capabilities of their model were comparable to that of the model written in FORTRAN language. Spero, 1985 [34] used the electronic spreadsheet to teach algorithms in mathematics. He demonstrated the use of the "Supercalc" spreadsheet package by solving three linear equations simultaniously. Kleinfeld, 1984 [19] presented the advantages of using general purpose programs for industrial engineering applications. Mendenhall, 1984 [23] demonstrated the use of the "Visicalc" electronic spreadsheet by calculating the job specifications or job standards sheets in operations where there were many product types with frequent changes in variable conditions.

Reviewing the previous work done, it is evident that most of it has been done in describing the beneficial uses of electronic spreadsheet, which is one of the modules of an integrated package, in industrial engineering studies. In construction management, the use of the electronic spreadsheet is demonstrated mostly in construction cost estimating. But there were no demonstrations to show the full procedure of the estimating cycle, which begins from the use of an organization's historical data to the graphical representation of the estimate. Although the use of integrated software packages in construction management was recognized by a few researchers, no attempt was made, by any of them, to demonstrate the use of an integrated package by modelling real life construction management functions. Since the necessity of graphical representation of construction management functions is increasing [10,16], integrated packages can be of great use because of their graph generating capabilities.

The computer utilization survey showed that of all the contractors, only seven were using general purpose programs for their data processing needs. It was found from interviews of five of them including a personal demonstration by one [36] in St.John's, Newfoundland, that they were using these packages for estimating purpose only.

After these interviews and a comprehensive review of the literature on construction management functions, integrated package applications for construction management functions were developed, using the IBM personal computer, at the Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St.John's, Canada. These applications were demonstrated to construction and engineering personnel at the various continuing engineering education seminars at Memorial University of Newfoundland, Canada. Constructive suggestions solicited at these demonstrations were incorporated into the integrated package modules producing powerful solution tools that are capable of solving a wide range of construction management functions.

Integrated software packages are fully described in Chapter 2 and a number of models of construction related problems developed on an integrated package "Lotus 1-2-3" are presented in Chapter 3.

The survey results had also indicated that the contractors with little or no experience in computer data processing wanted to computerize their data processing needs, yet they were uncertain of the process by which the computer system should be selected. Therefore, criteria for the selection of a complete computer system are defined in this study. For this purpose, a vast amount of information was obtained from hardware and software vendors, service bureaus, short course presentations, computer use seminars, and recent computer software surveys. The criteria for the selection of a complete computer system are described in detail in Chapter 4.

Summary and research conclusions are discussed in Chapter 5.

Chapter 2

INTEGRATED SOFTWARE PACKAGES

2.1. INTRODUCTION

Integrated software packages are a recent introduction to microcomputer software. The first integrated package appeared on the market in 1983 [17] under the trade name Lotus 1-2-3. Since then a number of integrated packages have been introduced in the market. These integrated packages are simple in concept but sufficiently powerful to solve extremely complex data processing problems. Some major features of these systems are discussed in this chapter.

The most impressive feature of integrated packages is the fact that the users need no prior experience in computer programming and no knowledge of a programming language because the integrated package language does not resemble a usual programming language. Its language consists of a series of commands and functions which can be easily mastered. This offers the user greater flexibility in writing programs. This one feature by itself makes integrated package user- oriented.

Integrated software packages combine an electronic spreadsheet with two or more other modules. Usually, data base management, graphics, and word processing modules are combined with the electronic spreadsheet. Each of these modules is described as follows:

ELECTRONIC SPREADSHEET MODULE: Electronic spreadsheet programs are versatile tools for processing numbers in relatively short period of time. Like conventional pencil-and-paper worksheet, electronic spreadsheets organize data in a matrix of rows and columns. Each intersection of a row and column forms a storage location called as "cell". In each cell either a label, a value, or a equation can be placed, or the cell can be left blank. Long words or labels can be produced by coordinating cells. There is almost no limitation on the size of the value stored in a cell. The cells can be linked together by making reference to their coordinate numbers. This feature enables mathematical expressions to be combined to form complicated equations. This type of program format gives the user great freedom and versatility in writing programs.

DATA BASE MANAGEMENT MODULE: A data base is an electronic storage place for data. A wide variety of data could be stored; including financial, accounting, manufacturing, scheduling, and costing data. Data base management programs manipulate the data to build tables and charts which allow easy visual comparison of data. This organized data can then be used for further analysis.

WORD PROCESSING MODULE: Word processing programs are means of computerizing the typing effort of an individual or an office. The word processing programs greatly increase the efficiency of typing effort, allowing rapid editing, production, copying, etc., of typed material.

GRAPHICS MODULE: Graphics packages can produce simple graphics, bar graphs, line graphs, pie charts, etc. Some packages have the ability to manipulate statistical data after entry and display the results graphically in several types of charts.

Generally, each of the above mentioned programs is developed independent of the other. As a result it is a frustrating task, for example, to attempt to place a chart developed on a graphic program into an electronic spreadsheet. The commands for performing the same functions on the two programs are likely to be contradictory and difficult to recall. Integrated programs address this problem directly by combining a word processing program, a data base management program, an electronic spreadsheet, a graphics package, and other modules like communication, all into one program. Figure 2-1 shows the general concept of integrated software packages. The advantages of integrated packages are that they allow, for example, calculations from the spreadsheet to be entered into charts and tables built on the data base management program, and both can be entered in a word processing document, and also can be displayed graphically. The commands are consistent across all the programs, eliminating a great deal of frustration, and the cost is certainly less than the total of four different single-function programs of equal power.

Currently, there are a number of integrated packages available on the market. A list of popular integrated packages [7] is given in Appendix B. Most of these packages are diverse versions of the original Lotus 1-2-3 [29]. The differences in various packages are mainly between the size of the electronic spreadsheet

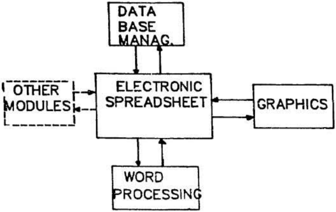


Figure 2-1: Integrated Software Package Structure

module and the number of modules which are integrated in one package. Another aspect of these integrated packages is the compatible hardware. Microcomputer software cannot run on any computer system. Hardware and software must be matched.

Although these integrated packages differ from each other in some features, they are similar in concept and structure. Most of the integrated packages marketed today have a capability of reading files written in other integrated packages. For example, "Symphony" is a new development in the integrated packages family, it can read files written in the "Lotus 1-2-3" package. So the modules developed in Lotus 1-2-3 can be converted to the Symphony modules. Moreover, a person familiar with one integrated package can easily learn to use other integrated packages. He/she just has to familiarize himself with the commands and the functions of the the new package. Therefore, it can be said that in utilizing the integrated packages, the important aspect is the knowledge or concept of integrated package rather than the type of integrated package used. The concept of integrated packages being the same, Lotus 1-2-3, one of the most popular integrated packages is described as an example in this study.

2.2. LOTUS 1-2-3 SOFTWARE

Lotus 1-2-3 is an integrated package that integrates graphics an' information management modules with an electronic spreadsheet. Lotus 1-2-3 was developed specifically for the IBM personal computer and uses every key on the keyboard. Lotus 1-2-3 is now available for almost every microcomputer [25].

The electronic spreadsheet module of Lotus 1-2-3 consists of 256 columns and 2048 rows. As Lotus 1-2-3's graphic module is integrated with the electronic spreadsheet module, the columns and rows of the electronic spreadsheet can be displayed graphically. With this facility "What If" projections can be played visually.

The display screen for Lotus 1-2-3 has three parts. The screen [20] is shown in Figure 2-2. At the top is the "control panel". Most of the rest of the screen is usually taken up by a section of the worksheet- maximum of eight columns and twenty rows. Separating the two is a border showing the column letters and row numbers of the section of the worksheet which is in view. The control panel has three lines. The first line contains information about the location, display format,

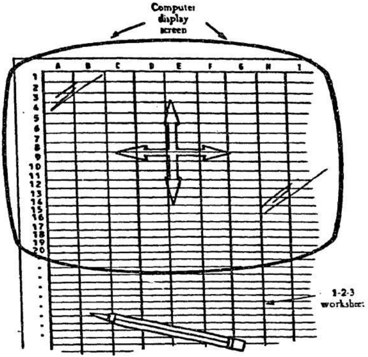


Figure 2-2: Lotus 1-2-3 Screen

protection status, and contents of the "current cell". At the right of the first line is the mode indicator. The second line displays one of three things: the characters of entries as typed or edited; menu item; or "prompts" asking for additional command specifications. Lotus 1-2-3 uses the third line to display quick summaries of command which the user is selecting. As the menu pointer is moved among the various command words before selection is made for one of them, Lotus 1-2-3 changes the third line so that its information always refers to the currently highlighted word.

The Lotus 1-2-3 commands are like a set of operating instructions. In order to operate Lotus 1-2-3 efficiently, a thorough knowledge of these commands is essential. Lotus 1-2-3 commands perform such functions as:

. Copying, moving, and deleting data from the worksheet.

. Performing mathematical calculations.

. Transferring data between the worksheet and disk storage.

. Printing reports.

. Drawing graphs.

. Handling data base.

Lotus 1-2-3 commands are organized into a multi-level menu system. Each command has a name, consisting of one or more command keywords. Users build up a command name by selecting one keyword at a time from the menu that Lotus 1-2-3 displays on the control panel. The complete set of instructions and command details are available in the users manual for Lotus 1-2-3 [20]. Hence no attempt is made to explain these commands in this section. Moreover, a tutorial diskett, which is provided with the purchase of the Lotus 1-2-3 software package is also useful in mastering these commands. To describe Lotus 1-2-3's versatility, a simple example is discussed below.

Consider a cost estimate made by a construction contractor. A BASIC program using microcomputer for this cost estimate is shown in Figure 2-3. The output from the BASIC estimating program is shown in Figure 2-4. The same estimating program can be written by using Lotus 1-2-3. Figure 2-5 shows a Lotus 1-2-3 form used for the same estimate. Input information for the coordinate locations, values and formulas, is shown in Figure 2-5. What is displayed on the screen is shown in Figure 2-6. On the top line is an entry location for placing the title of the estimate. Information required for estimating (description. quantity, unit, unit price,etc.) is placed on the third row. Under the column "Description" three work items are placed. The quantity of work to be performed, the unit, and its unit prices are placed in front of each work item under column two, three, and four. Sub totals for each work item are calculated, in column five, by multiplying the quantity by the unit price of each work item. The estimate total is calculated by adding the sub totals of all work items.

As graphic displays are basically more efficient ways to present information, the power and flexibility of Lotus 1-2-3 for creating visual representation of data are utilized and a graph representing an estimate is drawn. The graph is shown in Figure 2-7. The advantage of the Lotus 1-2-3 is its capability of "what if" graphing. Once the graph is defined it resides in the computer memory. Changing some of the data that goes into a graph does not invalidate the graph setting and

```
10 LPRINT TAB(30) "ESTIMATE WAREHOUSE" : LPRINT
20 LPRINT "DESCRIPTION", TAB(15) "QUANTITY", TAB(30) "UNIT",
   TAB(45) "UNIT PRICE", TAB(60) "SUB TOTAL" : LPRINT
30 PRINT "SITE WORK DATA" : INPUT  "QUANTITY";A : LINE INPUT
   "UNIT ?";D$ : INPUT "UNIT COST";G : PRINT
40 PRINT "EXCAVATION DATA" : INPUT  "QUANTITY";B : LINE INPUT
   "UNIT ?";E$ : INPUT "UNIT COST";H : PRINT
50 PRINT "CONCRETE DATA" : INPUT  "QUANTITY";C : LINE INPUT
    "UNIT ?";F$ : INPUT "UNIT COST";I : PRINT
60 J=A*G
70 K=B*H
80 L=C*I
90 M=J+K+L
100 LPRINT "SITE WORK",  TAB(15)  A, TAB(30) D$, TAB(45) G,
    TAB(60) J
110 LPRINT "EXCAVATION",  TAB(15) B, TAB(30) E$, TAB(45) H,
    TAB(60) K
120 LPRINT "CONCRETE",  TAB(15) C, TAB(30) F$, TAB(45) I,
    TAB(60) L
130 LPRINT : LPRINT TAB(45) "TOTAL", TAB(60) M
```

Figure 2-3: BASIC Program for Estimating Example

ESTIMATE WAREHOUSE

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	SUB TOTAL
SITE WORK	100	SQ.M	1000	100000
EXCAVATION	200	CY	2000	400000
CONCRETE	300	CY	3000	900000
			TOTAL	1400000

Figure 2-4: Output from BASIC Estimating Program

	A	B	C	D	E
1		ESTIMATE OF WAREHOUSE			
2		---------------------			
3	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	SUB TOTAL
4					
5	SITE WORK	100	SQ.M	1000	B5*D5
6	EXCAVATION	200	CY	2000	B6*D6
7	CONCRETE	300	CY	3000	B7*D7
8					
9				TOTAL	@SUM(E5..E7)
10					

Figure 2-5: Lotus 1-2-3 Program for Estimating Example

	A	B	C	D	E
1		ESTIMATE OF WAREHOUSE			
2		---------------------			
3	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	SUB TOTAL
4					
5	SITE WORK	100	SQ.M	1000	100000
6	EXCAVATION	200	CY	2000	400000
7	CONCRETE	300	CY	3000	900000
8					
9				TOTAL	1400000
10					

Figure 2-6: Output from the Lotus 1-2-3 Estimating Program

the most recent graph can be redrawn by pressing only one key on the keyboard. For instant, the quantity of work item "Excavation" which is 200 sq.m. is changed to 500 sq.m. in the Figure 2-6. The graph, as shown in Figure 2-8, is redrawn by pressing a single key on the keyboard.

The above examples demonstrate the versatility of Lotus 1-2-3 as compared to that of programming languages. Apart from these graphic and data manipulation features mentioned above, there are a number of trigonometric, arithmetic, logical, and information management functions which are built into the Lotus 1-2-3 system. These functions provide added capability in writing equations and performing other operations. Most of these functions were found to be very helpful for the applications of Lotus 1-2-3 in modelling construction management functions, described in Chapter 3.

It can be seen that integrated packages are essentially simple general purpose programs, with a library of commands and functions. As the user becomes more proficient in integrated packages. he/she will discover that the simplicity of these programs is not a hinderance at all. In fact, with some imagination, these integrated packages can be used to perform in ways that were probably unforseen in commercially available application software. With a view to demonstrating the ability of using integrated packages in construction, several construction management functions are modelled on Lotus 1-2-3, and these are detailed in the following chapter.

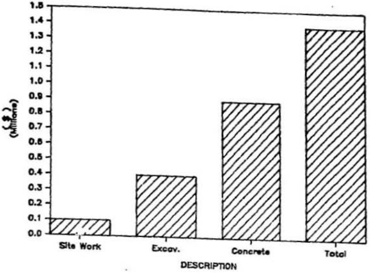


Figure 2-7: Graphical Representation of Estimate

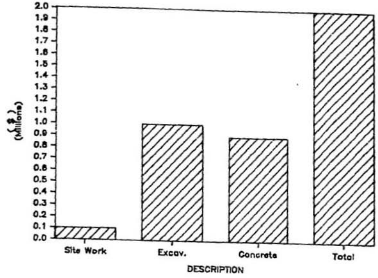


Figure 2-8: "What If" Graphing Result

Chapter 3

MODELLING CONSTRUCTION MANAGEMENT FUNCTIONS ON AN INTEGRATED PACKAGE

Contemporary use of integrated packages has centered on financial- and accounting- type analysis. Models are described in this chapter that facilitate the use of an integrated package for analyzing several construction management functions. The models developed on an integrated package have some merits and advantages over other means of modelling construction management functions. The most important aspect of these models is that no programming background is required to build such models, whereas extensive knowledge of a programming language such as BASIC or FORTRAN would be necessary to build the same models by programming. Moreover, it is easier for the user to understand a model's logic when the model is written using simple integrated package notations than through a FORTRAN, or BASIC - coded form. Some of the major merits of the integrated package are their visual feedback and analytical and graphical capabilities.

An integrated package, Lotus 1-2-3 is used to demonstrate its potential applications in the construction industry. Prior to describing the various models for construction management functions, the common construction management functions are described below.

3.1. CONSTRUCTION MANAGEMENT FUNCTIONS

Construction management functions can be broadly classified under the following categories [2].

1. Engineering

2. Project Appraisal and Control

3. Equipment Cost Analysis

4. Administration

Various functions that are commonly performed under each category are shown in Figure 3-1. All these functions are modelled on an integrated package "Lotus 1-2-3", and are described in the following sections.

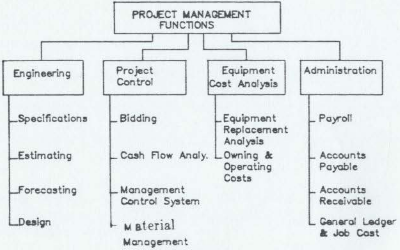


Figure 3-1: Classification of Construction Management Functions

3.2. SPECIFICATIONS

In construction process usually three parties are involved, the owner, the architect/engineer, and the contractor. The owner may be referred to as the client, employer, or promotor. The owner is responsible for providing money and all information for execution of the project. The engineer's responsibility is to consider the feasibility of the project and to prepare a safe design at the lowest cost. The engineer then provides contractors, who intend to bid, or tender, for the execution of the works or project, with a set of contract documents.

Contract documents consist of two packages which describe the structures to be built. One package consists of drawings which provide dimensional information on the project-location, size, and relationship. The second package is the book of specifications which establishes quality, performance, and methods to be employed [27].

It is a common practice among construction organizations to keep standard specifications for each subject. Modifications to the standard specifications are made, to meet the requirements of particular project, by writing the special provisions in contract documents. In using this system several problems arise. These are:

1. Contractors sometimes claim that the standard specifications and special provisions are in conflict when the two say different things about the same subject or item.

2. Occasionally, the standard specifications contain material that does not apply to a given project, thus causing confusion.

3. There is a tendency to incorporate a standard specification into

contract documents without appropriate review or revision for conformance with current technology and new informatioa.

4. Specifications are not always well organized and it is difficult to find subjects quickly.

5. Engineers have to write new special provisions for every project, consuming valuable time and often creating ambiguous specification wording.

6. Typing personnel have to type special provisions for each project, again consuming valuable time.

These problems can be overcome by developing a computerized specification system. Various organizations, such as Production Systems for Architects and Engineers (PSAE) USA, Public Building service (PBS) USA, etc., provide computerized master specifications. The key question is whether these broad master specifications serve the diversified needs of all organizations. Since there is no single master specification that fits the needs of every organization, every user writes the specifications, based on his/her own experience, judgement, and the type of work performed by the organization.

Word processing packages provide a solution for this problem by allowing the users to design a specification system based on their particular needs and practices. As most of the integrated packages have a capabality of word processing, they can also be used for modelling a specification system. A typical specification system is modelled by using an integrated package Lotus 1-2-3 to show the prospective use of these packages in this area. The description of the module is as follows:

3.2.1. Computer Module

In computerizing the specification system, a master specification for each subject is developed and stored in the floppy disk under separate file name. A block diagram of procedure for computerized specification system is shown in Figure 3-2, and is explained below.

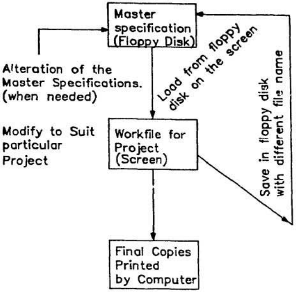


Figure 3-2: Flow Diagram-Computerized Specification

1. Master specifications for each subject are stored in a separate Lotus 1-2-3 file in a floppy disk. When project specifications are needed, the required master specification is selected from a library of master specifications and is loaded in the computer.

2. The master specification is then edited or changed to suit a particular project. This revised master specification file is considered as a separate workfile. and is

saved in the floppy disk under a separate file name. In this manner the master specification is kept unchanged.

3. The workfile specifications can then be printed on the printer at the same time or later.

4. Master specifications are modified periodically to incorporate the new procedures, experiences, etc.

Using the above mentioned procedure, an example on Lotus 1-2-3 specification system is presented. A master specification of "Structural Steel" [14] is shown in Figure 3-3. The changes made on master specification sheet are shown in Figure3-4. The revised specification sheet, which will be included in the contract documents, is shown in Figure 3-5.

There are number of benefits in using the computerized specification system. The personal actually writing and editing the specifications will appreciate the system the most because it is quicker to write specifications with computers. Computerized specifications make it easier to design the project since the master copies contain notes reminding the user to consider certain design items in the project and to discuss various facts with the persons in other disciplines. In addition, the reminder notes can easily be updated periodically. The typing personnel will prefer the computerized system over the old one because it is much easier and quicker to produce almost error-free work. Moreover, with the computerized specification system, it is simpler to incorporate the clients' preferences and requests because of the ease in editing the specifications.

MASTER SPECIFICATION

STRUCTURAL STEEL DATED 01-01-1985

1. Submit certified copies of mill test reports for all steel furnished. Perform mechanical and chemical test for all material regradless of thickness or use. No part of the ASTM specifications will be waived without consent of the Architect.

######### OPTION A-2 ##########

2. Submit certified ststement from the base metal manufacturer that the proposed welding material and techniques proposed for weathering steel will produce weldments meeting the specified requirements under actual project conditions.

1.4 PRODUCT HANDLING
----

a. Do not handle structural steel until paint has thoroughly dried. Care shall be exercised to avoid abrasions and other damage.

b. stack material out of mud and dirt and provide for proper drainage. Protect from damage or soiling by adjacent construction operations.

########## OPTION A-2 ###########

c. Weathering steel shall be stacked and/or handled in a manner which will prevent staining.

PART 2- PRODUCTS

2.1 MATERIAL
----

a. Structural Steel: ASTM A 36 unless otherwise shown.
######## OPTION A-2 #########
b. Weathering Steel: ASTM A588 Grade A or B unless otherwise shown.
######### OPTION C ##########
c. High-Strength Bolts and Nuts: ASTM A325 and ASTM A490, minimum 3/4 in. diameter

Figure 3-3: Original Unedited Master Specification

~~MASTER SPECIFICATION~~ PROJECT XYZ
ANYWHERE, CANADA

STRUCTURAL STEEL ~~DATED 01-01-1985~~

Delete option 2

1. Submit certified copies of mill test reports for all steel furnished. Perform mechanical and chemical test for all material regradless of thickness or use. No part of the ASTM specifications will be waived without consent of the Architect.

   ######### OPTION A-2 #########

2. Submit certified ststement from the base metal manufacturer that the proposed welding material and techniques proposed for weathering steel will produce weldments meeting the specified requirements under actual project conditions.

1.4 PRODUCT HANDLING
----

a. Do not handle structural steel until paint has thoroughly dried. Care shall be exercised to avoid abrasions and other damage.

b. stack material out of mud and dirt and provide for proper drainage. Protect from damage or soiling by adjacent construction operations.

   ########## OPTION A-2 ##########

c. Weathering steel shall be stacked and/or handled in a manner which will prevent staining.

PART 2- PRODUCTS

2.1 MATERIAL
----

a. Structural Steel: ASTM A 36 ~~unless otherwise shown.~~ and A440 as Show in Fig. 1

   ######## OPTION A-2 ########

b. Weathering Steel: ~~ASTM A588 Grade A~~ or B unless otherwise shown.

   ~~######### OPTION C #########~~

c. High-Strength Bolts and Nuts: ASTM A325 and ASTM A490, minimum ~~3/4~~ 1" in. diameter

Figure 3-4: Master Specification Edited for New project

PROJECT XYZ
ANYWHERE, CANADA

STRUCTURAL STEEL

1. Submit certified copies of mill test reports for all steel furnished. Perform mechanical and chemical test for all material regardless of thickness or use. No part of the ASTM specifications will be waived without consent of the Architect.

1.4 PRODUCT HANDLING

a. Do not handle structural steel until paint has thoroughly dried. Care shall be exercised to avoid abrasions and other damage.

b. stack material out of mud and dirt and provide for proper drainage. Protect from damage or soiling by adjacent construction operations.

PART 2- PRODUCTS

2.1 MATERIAL

a. Structural Steel: ASTM A 36 and A440 as shown.

b. High-Strength Bolts and Nuts: ASTM A325 and ASTM A490, minimum 1 in. diameter

Figure 3-5: New Project Specification Lotus 1-2-3 Printout

In conclusion it can be said that with an established computerized specification system, users can produce specifications with less effort and time, and in a better way than the traditional methods.

3.3. ESTIMATING

Estimating is an essential prerequisite for practically all construction projects. Whether the contract is competitively bid, negotiated, design-construct, or construction management, some form of estimating is essential. The success or failure of construction organizations depend to a great extent upon their estimating capability. Since most projects are competitively bid, the estimate must be low enough to outbid the competition yet still generate a profit. Considering the environment in which most projects are estimated, competitive bidding becomes an extremely challenging task. Projects that last two years or more, may be estimated in less than a month. Other factors that complicate the estimate are: weather, location, labor supply, and site conditions. When the importance of the task and the conditions under which it is performed are considered, estimating can not be described as a science but rather an art

Even though estimating may be an art or skill, the method is constantly being improved. Within recent years there has been an increase in the use of computers for estimating. Estimating software packages are available for all three types of computers. However, most of these software packages are not as flexible as the user would like. The estimating methods and procedures in construction are probably as varied as the number of contractors in the industry. Because of this personal touch in estimating, most contractors may find it difficult to estimate on the computer. Integrated packages could remove most of these objections. Because of integrated packages' flexible format it can be adopted to any specific estimating format.

Seven contractors who participated in a computer utilization survey were using electronic spreadsheets or integrated packages for estimating purposes and were satisfied. These contractors were, therefore, contacted for personal interviews. Based upon their inputs and the basic principles of estimating, an estimating module was developed by using Lotus 1-2-3. This module is described as follows:

3.3.1. Computer Module

Most estimates include a takeoff or quantity survey form, a pricing form, and a recap form. The use of organizations' own historical data in estimating is also a very common practice. These essential parts are included in this application. Most likely the style of the forms, developed on Lotus 1-2-3, will vary with the contractor, but the basic principles and calculations should essentially be the same.

When estimating a project the work items are usually categorized in some manner. Breaking the project items into groups such as concrete work, site work, mechanical work, and so on simplifies the job for the estimator. One way to group the work items on a project is to follow some type of format. This format would be followed each time a new project is estimated to prevent work items from being omitted. A format that is typical of those used frequently in the construction industry is the master format published by the Construction Specifications Institute (CSI) of Washington, D.C. The format published by the CSI consists of sixteen divisions for different work items such as site work, concrete, metals, etc.

The flow diagram of the estimating program is illustrated in Figure 3-6. Each work item division (Div 1, Div 2, ...) is stored in separate Lotus 1-2-3 file or sheet. The sheets are then linked for transferring the data between divisions. Figure 3-6 shows a linking of these various work item sheets. For simplicity, only work item Metals which is DIV. 5 in CSI is considered for demonstrating the application of Lotus 1-2-3 for estimating.

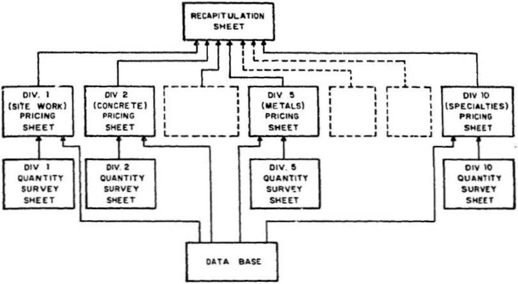


Figure 3-6: Flow Diagram of Estimating Program

A Lotus 1-2-3 estimating program is set up in such a manner that the quantity survey and pricing forms are on one sheet. These two forms are shown in Figure 3-7 and Figure 3-8. As these two forms are developed on the same sheet, they are stored on a floppy disk under the same file name. A data base is developed on a separate sheet, which feeds the data to the pricing sheet, and is illustrated in Figures 3-9 and 3-10. The replication form is placed on an individual sheet and therefore stored on the disk under the separate file name. An explanation of all the forms (i.e quantity survey, pricing, data base, and replication forms) and method of their integration follows:

QUANTITY SURVEY FORM: The quantity survey form as illustrated in Figure 3-7 is a form where take-off materials are recorded and quantities calculated. The first column on the form is for the item number. For this particular division there are three different items. They are; structural metal, bar joists and bridging, and metal decking. The second column is for describing the individual pieces of material. The third column is for placing the number of pieces of a particular item. The next three columns are for dimensions of the item. This is followed by the unit weight column. In the subtotal quantity column a formula is placed which automatically calculates the quantity by multiplying the length, width, and height by the number of items and unit weight. The last location in the subtotal column adds all the values above it for a particular work item. For example item 5100 has subtotal calculated for the different structural components. This total is converted into a pay item quantity and transferred to the total column. Steel is estimated by the tonnes so this conversion is made in the total quantity column by dividing the subtotal quantity, which is in kilograms, by 1000. The last column is provided for any remarks that the estimator would like to document.

From an examination of the quantity survey form, it is apparent that spaces appear in different columns and some zeros in the subtotal column. This is to allow an area for placing additional material. For each particular item the use and size of these work areas will vary from project to project. For example, eight rows are allowed for entering the different beam sizes. Only three different beam sizes are shown in this example. That leaves five available rows for additional beams. The value at the bottom of the subtotal column is the total of eight values and is calculated by using the appropriate function of Lotus 1-2-3. What if there are nine or more different beam sizes and the form is set up for eight different beams? This is not a problem for any integrated package because the insert command can be used to insert as many rows as needed after the last beam entry. Then place the necessary information and copy the formula from any subtotal quantity cell to the cells in the newly inserted rows under the subtotal quantity column. The integrated package will automatically adjust the formula at the bottom of subtotal quantity and calculates the sum of the subtotal quantities in all the items, including the newly inserted items, above it.

This shows the great flexibility of an integrated package on estimating quantity take-off sheets. The estimator has total control and freedom in placing take-off items into the computer. Regardless of the number of items, the formulas behind the subtotal sum and the total locations are adjusted by the integrated package. The different item numbers and their subdivisions can be set up to conform the contractor's own estimating format. The complete worksheet can be structured to match whatever format the contractor is familiar with.

THE PRICING FORM AND THE DATA BASE: The pricing form. Figure

3-8, is placed on the same Lotus 1-2-3 sheet as the quantity survey form. The total quantity of each item is transferred automatically from the quantity survey form to the pricing form thereby eliminating the chance of the wrong value being used on the pricing form. This is another advantage of using integrated packages. The pricing form is also integrated with the data base. In the data base sheet, standard crews, along with their daily work output and daily costs are stored. An explanation of the data base and how to extract appropriate data from the data base sheet and place it in the pricing sheet is given below.

Most of the organizations maintain historical records of man-hours expended for various tasks, composition of crew and their output, material prices, construction methods related to particular items and so on. It is a common practice in the construction industry to consult historical records during the estimation. This important aspect of the estimating process is illustrated by developing a data base (Figure 3-9 and Figure 3-10) using the information from the "MEANS" Construction Cost Data Handbook, published by Robert Snow Means Company, Inc., Kingston, MA. Hourly base wage rates, fringe benefits, and total wage rates of forty key construction trades are placed in the data base sheet as shown in Figure 3-9. Each crew consists of various trades and equipment as illustrated in Figure 3-10. The hourly cost of the appropriate trade is obtained automatically from the trade list. The daily cost for each trade is calculated by multiplying the hourly cost of the number of men by the number of hours (8) per day. Both the wage rates of various trades and the crews costs are developed on the same sheet and are stored on the floppy disk, under the same file name. Whenever the wage rate of any trade is changed, the Lotus 1-2-3 automatically updates the crew costs. This updated information is then transferred to the pricing sheet.

The pricing sheet (Figure 3-8) is where the job items materials, labors, and equipment costs are computed and combined. An explanation of the pricing sheet will reveal some more advantages in using integrated package in project estimating.

The title information of the pricing form is identical to that of the quantity survey form. The first two columns are the same and are drawn automatically from the quantity survey form. The third column contains the quantities transferred automatically from the quantity survey form. The material cost column is where the estimator inserts the material price per unit. The program then takes these values, multiplies them by the relevant quantities and places them in the total material cost columns.

The columns under labor and equipment costs use the information from the data base sheet. Here, the macro facility of Lotus 1-2-3 is utilized. Macro facilities of Lotus 1-2-3 allows to store sequences of keystrokes for future use (Macro facilities are fully explained in Lotus 1-2-3 user's manual[20] at page 109). Once a macro facility is invoked and appropriate information is entered , the macro command makes the system extract relevant data (trades and equipment used to make a crew, their daily costs, and daily output) from a data base sheet and places it at the proper location on the pricing form (see Figure 3-8). If the user wants to change any of the information, he just has to overwrite the new information in the appropriate cell. This again is one of the advantages of using integrated packages. Total labor and equipment costs are calculated by using the total quantity, daily cost and daily output. In the last column of the pricing sheet the total item cost is calculated by adding the total material, labor and equipment costs.

THE RECAPITULATION FORM: The recapitulation form is the final estimating form in this Lotus 1-2-3 application. It is placed on a separate Lotus 1-2-3 sheet and is, therefore, a separate file. On the recapitulation form (Figure 3-11) the costs for the different work items are assembled to determine the bid figure. This form, like the others, contains a title heading for placing job information. The column headings indicate where the different item costs should be entered. The bottom portion of the form contains the locations for adding in the tax, contingency, and overhead and profit. An entry location is available for inputing these values.

The recapitulation form can be expanded or contracted , just like the quantity survey and pricing forms, by using the insert and delete commands. These two commands give the user great flexibility in handling and assembling the item costs. The recapitulation form, by using the macro facility of Lotus 1-2-3, is structured in such a way that whenever the recapitulation sheet is loaded from the floppy diskett onto the screen it collects information from all division files automatically. As in this example there is only one division sheet so the Lotus 1-2-3 brings the information about the Div.5 as shown in Figure 3-11. The user has to enter the values of tax, contingency, and overhead. Once these values are entered on the recapitulation form, Lotus 1-2-3 adds the costs, the tax, contingency, and overhead and profit to calculate the total amount. This finishes the description of the basic parts of the Lotus 1-2-3 estimating example.

There are many advantages in using integrated packages for estimating. Unlike other estimating software packages, integrated packages allow the contractor to still use the same forms he is accustomed to using. The flexibility of integrated packages allows the users to expand the forms to include the necessary work items. This gives the users lot of capability in revising and changing work items that are affected in addendums. Another advantage is the ability to change input values and have the computer automatically recalculate the bid. For instance, it is not uncommon for the contractor to receive supplier and subcontractor prices only hours before the bid opening. Using an integrated package these last minute changes can be made very easily and the bid can be retabulated. This could prevent mistakes. The integrated package also gives the user the ability to play with the estimate or bid. The contractor may want to unbalance the bid by changing various work items. This can be done very effectively with an integrated package. A final advantage is the time, manpower, and money that is saved by estimating a project on an integrated package.

QUANTITY SURVEY SHEET

Project Name : CATARM	MEMORIAL CONSTRUCTION CO.	Work Category :Metals
Location : Grand Falls	ST. JOHN'S, NEWFOUNDLAND	Division : 5
Owner : Government	CANADA	Estimate Date :01/30/1985

ITEM NO.	DESCRIPTION	NO.	DIMENSIONS LENG. (m)	WIDTH (m)	HEIGHT (m)	UNIT WEIGHT	SUBTOTAL QUANTITY	UNIT	TOTAL QUANTITY	UNIT	REMARKS
5100	STRUCTURAL METAL										
	BEAMS										
	W8#10	5	22			10 kg	1100	kg			
	W8#16	25	20			16 kg	8000	kg			
	W12#26	45	30			26 kg	35100	kg			
							0	kg			
							0	kg			
							0	kg			
							0	kg			
							0	kg			
							44200	kg	44.2	TONNES	
	COLUMNS										
	W8#20	15	25			20 kg	7500	kg			
	W12#40	50	22			40 kg	44000	kg			
	W6#15	6	12			15 kg	1080	kg			
							0	kg			
							0	kg			
							0	kg			
							0	kg			
							0	kg			
							0	kg			
							0	kg			
							52580	kg	52.58	TONNES	
5200	JOIST&BRIDGING										
	BH3	30	15			5 kg	2250	kg			
	T211.3	35	30			4 kg	4200	kg			
	T411.4	20	25			6 kg	3000	kg			
	T411.2		220			2 kg	440	kg			
							0	kg			
							0	kg			
							0	kg			
							0	kg			
							0	kg			
							9890	kg	9.89	TONNES	

Figure 3-7: Quantity Survey Form

5300 METAL DECKING					
22 GA.ROOF	160	100		16000 sq.m.	
				0 sq.m.	
				0 sq.m.	
				0 sq.m.	
				0 sq.m.	
				0 sq.m.	
				0 sq.m.	
				16000 sq.m.	160 SQUARES
MISC.					
PIPE	8	30	3.5 kg	840 kg	
STRIP	10	50	2.5 kg	1250 kg	
				0 kg	
				0 kg	
				0 kg	
				0 kg	
				2090 kg	2.09 TONNES

Figure 3-7: Quantity Survey Form (Continued)

PRICING SHEET

Project Name :CATARM		Work Category :METALS
Location :GRAND FALLS	MEMORIAL CONSTRUCTION CO.	Division :05
Owner :GOVERNMENT	ST. JOHN'S, NEWFOUNDLAND	Estimate Date :01/30/1985
Designer :MUN	CANADA	Estimator :Bill Pelly

ITEM DESCRIPTION	QUANTITY TOTAL	QUANTITY UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR AND EQUIPMENT COSTS CRAFT	DAILY COSTS	DAILY OUTPUT UNIT	TOTAL LAB.&EQPT COSTS	TOTAL ITEM COSTS
5100 STRUCTURAL METAL									
BEAMS	44.2	TONS	$1,000	$44,200	E-9 1 WELDER FOREMAN 1 WELDER 4 GAS WELDING MACHINE,300 A 1 TRUCK, 3 TON	581.69	8.3 TONNES	$3,098	$47,298
COLUMNS	52.58	TONS	$900	$47,322	E-3 1 STR. STL. FOREMAN 1 STRUC. STEEL WRKS 1 WELDER 1 TORCH,GAS & AIR 1 GAS WELDING MACHINE,300 A	546.24	7.0 TONNES	$4,103	$51,425

Figure 3-8: Pricing Form

5200 JOIST & BRIDGING								
BH.3	9.89 TONS	$600	$5,934	E-10	$2,319	12.0 TONNES	$1,911	
				1 STR. STL. FOREMAN				
				4 STRUC. STEEL WRKS				
				1 EQPT. OPR. (CRANE)				
				1 OILER				
				1 WELDING FOREMAN				
				2 WELDERS				
				2 GAS WELDING MACHINE,300 A				
				1 CRANE, 90 TON				
								$7,845
5300 METAL DECKING								
22 GA.ROOF	160 SQRS.	$31	$4,960	E-13	$284	70.0 SQUAR	$650	
				1 WELDER FOREMAN				
				0.5 EQPT.OPR.,(LIGHT)				
				1 GAS WELDING MACHINE,300 '				
								$5,610
MISC.	2.09 TONS	$800	$1,672	E-14	$649	3.0 TONNES	$452	
				1 STR. STL. FOREMAN				
				3 STRUC. STEEL WRKS				
				1 GAS WELDING MACHINE,300 A				
								$2,124
					TOTAL DIVISION 5 COST			$114,302

Figure 3-8: Pricing Form (Continued)

ABBREVI-ATIONS	TRADE	BASE WAGE RATE(HRLY)	FRINGE BENEFITS	TOTAL WAGE RATE(HRLY)
CLAB	COMMON BUILD.LBR.	$15.60	$1.66	$17.26
ASBE	ASBESTOS WORKERS	$16.85	$2.36	$19.21
BOIL	BOILERMAKERS	$17.20	$2.26	$19.46
BRIC	BRICKLAYERS	$15.80	$2.40	$18.20
BRHE	BRICKLAYER HELPERS	$12.50	$1.40	$13.90
CARP	CARPENTERS	$15.30	$1.60	$16.90
CEFI	CEMENT FINISHERS	$15.50	$1.80	$17.30
ELEC	ELECTRICIANS	$17.40	$2.60	$20.00
ELEV	ELEVATOR CONSTRUCTORS	$16.95	$2.30	$19.25
EQHV	EQPT.OPRS.,CRANE OR SHOVEL	$16.00	$2.20	$18.20
EQMD	EQPT.OPRS.,MEDIUM EQPT.	$15.60	$1.90	$17.50
EQLT	EQPT.OPRS.,LIGHT EQPT.	$14.75	$1.20	$15.95
EQOL	EQPT.OPRS.,OILERS	$13.35	$1.00	$14.35
EQMM	EQPT.OPRS.,MASTER MECHANICS	$16.75	$2.10	$18.85
GLAZ	GLAZIERS	$15.10	$2.40	$17.50
LATH	LATHERS	$14.65	$1.87	$16.52
MARB	MARBLE SETTERS	$15.40	$1.96	$17.36
MILL	MILLWRIGHTS	$14.85	$1.63	$16.48
MSTZ	MOSAIC AND TERRAZZO WORKERS	$12.70	$1.11	$13.81
PORD	PAINTERS, ORDINARY	$17.45	$2.96	$20.41
PAPE	PAPERHANGERS	$16.60	$1.70	$18.30
PILE	PILE DRIVERS	$14.70	$1.23	$15.93
PLAS	PLASTERERS	$14.80	$1.28	$16.08
PLAH	PLASTERER HELPERS	$11.00	$1.05	$12.05
PLUM	PLUMBERS	$16.75	$2.40	$19.15
RODM	RODMEN (REINFORCING)	$17.30	$2.87	$20.17
ROFC	ROOFERS, COMPOSITION	$17.50	$2.97	$20.47
ROTS	ROOFERS,TILE & SLATE	$15.75	$2.10	$17.85
ROHE	ROOFERS HELPERS	$16.70	$2.50	$19.20
SHEE	SHEET METAL WKRS.	$14.85	$1.89	$16.74
SPRI	SPRINKLER INSTALLERS	$12.00	$1.29	$13.29
STPI	STEAMFITTERS OR PIPEFITERS	$17.75	$2.87	$20.62
STON	STON MASONS	$15.75	$1.76	$17.51
SSFM	STRUCTURAL STEEL FOREMAN	$18.30	$2.60	$20.90
SSWK	STRUCTURAL STEEL WKRS.	$16.70	$1.23	$17.93
TILF	TILE LAYERS(FLOOR)	$14.85	$2.05	$16.90
TILH	TILE LAYER HELPERS	$12.00	$1.30	$13.30
TRLT	TRUCK DRIVERS, LIGHT	$12.35	$1.40	$13.75
TRHV	TRUCK DRIVERS, HEAVY	$12.60	$1.20	$13.80
SSWL	WELDERS, STRUCTURAL STEEL	$16.70	$1.40	$18.10
WLDF	WELDER FOREMAN	$18.20	$2.98	$21.18

Figure 3-9: Various Construction Trades

CREW NO.	HOURLY COST	DAILY COST		DAILY UNIT OUTPUT
E1				
1 WELDER FOREMAN	$21.18	$169.44		
1 WELDER	$18.10	$144.80		
1 EQPT. OPR. (CRANE)	$18.20	$145.60		
1 GAS WELDING M/C,300A		$51.20		
	DAILY TOTAL	=	$511.04	4.8 TONS
E2				
1 STR. STL. FOREMAN	$20.90	$167.20		
4 STRUC. STEEL WRKS	$17.93	$573.76		
1 EQPT. OPR. (CRANE)	$18.20	$145.60		
1 OILER	$14.35	$114.80		
1 CRANE, 90 TON		$756.00		
	DAILY TOTAL	=	$1,757.36	5.5 TONS
E3				
1 STR. STL. FOREMAN	$20.90	$167.20		
1 STRUC. STEEL WRKS	$17.93	$143.44		
1 WELDER	$18.10	$144.80		
1 TORCH, GAS & AIR		$39.60		
1 GAS WELDING MACHINE, 300 A		$51.20		
	DAILY TOTAL	=	$546.24	7.0 TONS
E4				
1 STR. STL. FOREMAN	$20.90	$167.20		
3 STRUC. STEEL WRKS	$17.93	$430.32		
1 GAS WELDING MACHINE,300 A		$51.20		
	DAILY TOTAL	=	$648.72	8.0 TONS
E5				
2 STR. STL. FOREMAN	$20.90	$334.40		
5 STRUC. STEEL WRKS	$17.93	$717.20		
1 EQPT. OPR. (CRANE)	$18.20	$145.60		
1 OILER	$14.35	$114.80		
1 WELDER	$18.10	$144.80		
1 CRANE, 90 TON		$756.00		
1 TORCH, GAS & AIR		$39.60		
1 GAS WELDING MACHINE,300 A		$51.20		
	DAILY TOTAL	=	$2,303.60	11.0 TONS

Figure 3-10: Standard Crew

RECAPITULATION SHEET

Project Name : CATARM		Estimate Date :	01/30/1985
Location : GRAND FALLS	MEMORIAL CONSTRUCTION CO	Estimator :	Steve Dodge
Owner : GOVERNMENT	ST. JOHN'S, NEWFOUNDLAND		
Designer : MEMORIAL CONST. CO.	CANADA		

DIV.NO	ITEM	MATERIAL	LABOR & EQUIPMENT	SUBCONTRACTOR	TOTAL
1					
2					
3					
4					
5					
	5100 STRUCTURAL METAL	$91,522	$7,201		$98,723
	5200 JOIST & BRIDGING	$5,934	$1,911		$7,845
	5300 METAL DECKING	$6,632	$1,102		$7,734
6					
7					
8					
9					
10					
TOTAL HARD COST		$104,088	$10,214	$0	$114,302
TAX (%)	6.00%				$6,245
CONTIGENCY (%)	10.00%				$12,055
O.H & PROFIT(%)	15.00%				$19,890
TOTAL BID					$152,492

Figure 3-11: Recapitulation Form

3.4. FORECASTING

Forecasting is said to be sometimes a science, sometimes an art, and most often a little of both. The usual approach to forecasting involves extrapolation of past data into the future using linear or non-linear relationships and mathematical expressions. The estimator may be concerned with periodic observations of labor and materials costs, and other prices. The characteristics of these observations may be described as constant, variable, trend cycle, seasonal, or regular. All these observations suggest some type of "time series" analysis in order to predict the future trends. Depending on the characteristics of these observations, the estimator chooses an empirical graph that approximates local segments of the observed time series to forecast future events.

As the forecasting process relies mostly on assumptions, and these assumptions are made throughout the forecasting process, it is important that the user himself should make the choice of them. Integrated packages provide this flexibility by providing an increased control of the forecasting process to the user. One such application is demonstrated by developing a material cost forecasting module on Lotus 1-2-3 . The computer module is explained as follows.

3.4.1. Computer Module

There are different methods of forecasting the material prices. Most of these methods utilize the past data to find the trend and project it in the future. Generally, the first step of this process is to look at the trends and establish the type of method to be used. The material cost forecasting example considered for this study has seasonal trends (i.e., the price varies with the time of the year). The forecasting method to solve a seasonal trend problem is essentially a three step algorithm [4]. The first step is the detection of the seasonal factors, which is followed by the seasonal adjustments and smoothing of the actual data. The final step is the forecasting of the prices of material based on past trends. Each step of the algorithm is explained below.

Detection of Seasonal Factors: Quarterly data for five years for a material "X" is considered for this example. The plotting (Figure 3-13) of the data (Figure 3-12) shows that the data have seasonal variations. In order to adjust the data for seasonal effects, seasonal factors for each quarter are calculated and are shown in Figure 3-14. The quarterly data values are converted to a percentage of the total yearly values and averages for each quarter are calculated. The average percent values are then translated to base of 1 by multiplying by the number of periods in a year (If the comparison is on the basis of 3 months, it is multiplied by 4; if on each month of the year, by 12, and so forth). For example, the first quarter with an average of 22.95% of the year would have a seasonal factor of 4 x 22.95% = 0.918. After detecting the seasonal factors, seasonal adjustment is made and the data is smoothed.

Seasonal Adjustments and Smoothing: Seasonal adjustments are done by dividing the actual data values of each period with their corresponding seasonal factor value (Figure 3-15). After seasonal adjustment. it is often recommended [4,6] that the next step should be to smooth out minor fluctuations so that the general direction of movement can be discerned and projected to provide the basis for a forecast.

MATERIAL "X" COST DATA				
YEAR	QUARTER			
	1	2	3	4
1980	$102	$106	$110	$109
1981	$112	$110	$130	$128
1982	$130	$138	$148	$146
1983	$159	$167	$194	$192
1984	$200	$213	$240	$235

Figure 3-12: Material Cost Data

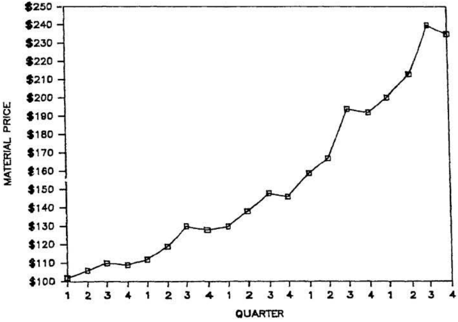


Figure 3-13: Cost Data Trend

PERCENTAGE OF TOTAL YEARLY COST BY QUARTERS				
YEAR	QUARTER			
	1	2	3	4
1980	23.89%	24.82%	25.76%	25.53%
1981	22.90%	24.34%	26.58%	26.18%
1982	23.13%	24.56%	26.33%	25.98%
1983	22.33%	23.46%	27.25%	26.97%
1984	22.52%	23.99%	27.03%	26.46%
Total	114.77%	121.17%	132.95%	131.12%
Average	22.95%	24.23%	26.59%	26.22%
Seasonal factor	0.918	0.965	1.064	1.049

Figure 3-14: Seasonal Factors Calculations

A number of techniques are available for smoothing. The most appropriate technique for seasonal variation is considered to be exponential smoothing [4], which is a type of moving average. It has the advantage that, instead of dropping out entirely, earlier data have diminishing effects. The speed of response can be controlled by the choice of weights, as is shown in the following formula:

α(adjusted data value)+(1-α)(previous smoothed value)

Where α is the weight factor, and the weights are found by the trial and error method for a suitable degree of smoothing. In the forecasting module, shown in Figure 3-15, provision is made for testing a number of the weight factor values. For each value of the weight factor, a smoothed value for each quarter is calculated. The smoothed values are then utilized to forecast the data in each

SEASONAL ADJUSTMENT AND EXPONENTIAL SMOOTHING OF DATA

YEAR	QUARTER	SEASONAL FACTOR	ACTUAL DATA	SEASONALLY ADJUSTED DATA	SMOOTHED VALUES WITH WEIGHT FACTOR 0.9	0.5	0.2	FORECAST VALUES WITH WEIGHT FACTOR 0.9	0.5	0.2
1980	1	0.918	102	111	107	107	107	98	98	98
	2	0.969	106	109	109	108	107	106	105	104
	3	1.064	110	103	104	106	107	111	113	114
	4	1.049	109	104	104	105	107	109	110	112
1981	1	0.918	112	122	120	113	108	110	103	99
	2	0.969	119	123	123	118	110	119	114	106
	3	1.064	130	122	122	120	112	130	128	119
	4	1.049	128	122	122	121	114	128	127	119
1982	1	0.918	130	142	140	130	117	128	120	107
	2	0.969	138	142	142	136	121	138	132	117
	3	1.064	148	139	139	138	124	148	147	132
	4	1.049	146	139	139	139	127	146	145	133
1983	1	0.918	159	173	170	154	132	156	142	122
	2	0.969	167	172	172	163	139	167	158	134
	3	1.064	194	182	181	172	145	193	183	155
	4	1.049	192	183	183	178	152	192	186	159
1984	1	0.918	200	218	214	196	161	197	180	147
	2	0.969	213	220	219	208	170	212	201	165
	3	1.064	240	226	225	216	179	239	230	191
	4	1.049	235	224	224	220	187	235	231	197

Figure 3-15: Seasonal Adjustments and Exponential Smoothings

quarter. Forecasted values obtained from selected weight factors are then compared with the actual values of the data to find the best weight factor value, which provides for the least forecast error. The comparison process for finding the appropriate α value is done graphically, and is shown in Figure 3-16. It is clear from the Figure 3-16 that the weight factor value of 0.9 is showing a close fit to the actual data line. Therefore, a weight factor of 0.9 is used for forecasting the cost in the next periods.

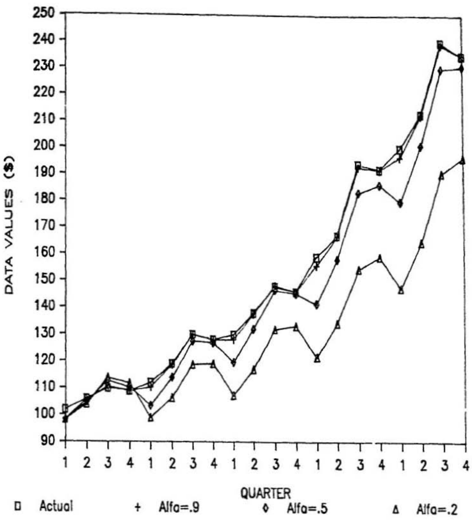


Figure 3-16: Effects of Exponential Smoothing

Forecasting: After the parameters have been chosen (α value and seasonal factors), the forecasts for the next periods are made. The forecasted values are shown in Figure 3-17. The smoothed value for the first quarter for 1985 is obtained as

Smoothed Value = α(1984 fourth quarter smoothed value)
+(1-α)(1984 first quarter smoothed value)

and the forecasted value for the first quarter of 1985 is obtained as:

Forecast value = (smoothed value)(seasonal factor)

The smoothed values and the forecasted values for the other three quarters of 1985 are calculated in a similar manner.

The advantage of using integrated packages in forecasting is that the user can incorporate judgements and experiences interactively. For example, in the above mentioned forecasting module developed on Lotus 1-2-3, various values of weight factors can be tested and analyzed graphically. User can also easily set the format on Lotus 1-2-3 in a similar manner, as discussed in this section, for a variety of forecasting problems.

FORECASTING BASED ON SELECTED
WEIGHT FACTOR & SEASONAL FACTORS

YEAR	QUARTER	SEASONAL FACTOR	ACTUAL DATA	SEASONALLY ADJUSTED DATA	SMOOTHED VALUE WITH ALFA 0.9	FORECAST VALUE WITH ALFA 0.9	FORECAST ERROR
1980	1	0.918	102	111	107	98	4
	2	0.969	106	109	109	106	0
	3	1.064	110	103	104	111	-1
	4	1.049	109	104	104	109	0
1981	1	0.918	112	122	120	110	2
	2	0.969	119	123	123	119	0
	3	1.064	130	122	122	130	0
	4	1.049	128	122	122	128	0
1982	1	0.918	130	142	140	128	2
	2	0.969	138	142	142	138	0
	3	1.064	148	139	139	148	0
	4	1.049	146	139	139	146	0
1983	1	0.918	159	173	170	156	3
	2	0.969	167	172	172	167	0
	3	1.064	194	182	181	193	1
	4	1.049	192	183	183	192	0
1984	1	0.918	200	218	214	197	3
	2	0.969	213	220	219	212	1
	3	1.064	240	226	225	239	1
	4	1.049	235	224	224	235	0
1985	1	0.918			223	205	
	2	0.969			223	216	
	3	1.064			224	238	
	4	1.049			224	235	

Figure 3-17: Forecasting Based On Previous Trends

3.5. DESIGN

Some contractors offer design services in conjunction with their construction capabilities. A common job for a building contractor is the design and construction of retaining walls.

The retaining wall is a structure built for the purpose of holding back or retaining or providing one-sided lateral confinement for soil or other loose material. Retaining walls are used in many design situations where there are abrupt changes in the ground slope. The most comman examples of the use of retaining walls are along the highway or railroad cuts and fills and locations such as bridge abutments, basement walls, and culverts.

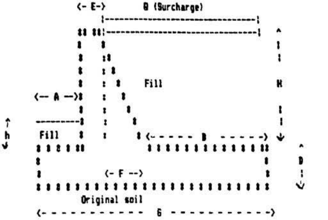
Retaining wall design begins with the selection of tentative dimensions, which are then analyzed for stability and structural requirements and are revised as required. Since this is a trial process, it is an ideal problem to be solved on an integrated package. A retaining wall design module is developed on the Lotus 1-2-3 integrated package and is explained as follows.

3.5.1. Computer Module

The Lotus 1-2-3 design module is shown in Figure 3-18. The program starts with highlighting the input data required. As in all design problems, some initial assumptions, such as initial footing and wall dimensions must be made; provision is made in the program to incorporate six sets of footing and wall dimensions. Once the assumed dimensions are inserted in the proper coordinate locations (as shown in Figure 3-18) the design computations are performed. Design calculations are fully explained in Appendix-C. The program checks the suitability of each set of footing and wall dimensions and selects the optimum set of dimensions. The optimization procedure is done on the Lotus 1-2-3 by using its information management facility. A table is generated (as shown in Figure 3-19) which extracts the values of safety factors for sliding and overturning, eccentricity, maximum soil pressure, allowable soil pressure for each set of dimensions. The program then selects the optimum set of dimensions based on the criteria, which is, safety factors for sliding and overturning should be between two and three, eccentricity should be less than G/6, and a maximum soil pressure should be less than an allowable soil pressure. The selected set of wall and footing dimensions are then used for calculating the steel required for the wall and footing. Finally the wall dimensions are shown at the bottom of the Figure 3-18.

This application demonstrates some of the advantages of using an integrated package in design problems. For simple design problems like this the designer can have computer capability without having prior experience with a computer programming language. The advantage is that, it is easily applicable to other design situations by inserting appropriate input information in the proper locations. Another advantage is the ease in changing design assumptions. In this example the footing and wall dimensions can be changed individually or collectively. This versatility in design assumption is something that cannot be offered by other design programs. The ability to project the answers into a visual picture is also an advantage of Lotus 1-2-3. Overall, these advantages as well as others were enjoyed in solving this design problem with an integrated package.

RETAINING WALL DESIGN



INPUT DATA

For Fill

Gamma1 = 17.95 kN/cubic m
Phi1 = 28 Deg.
C1 = 19.12 kPa

For Original Soil

Gamma2 = 19.53 kN/cubic m
Phi2 = 34 Deg.
C2 = 35.17 kPa
Allowable Soil Press. (qa) = 2000
(kN/sq. m)

For Concrete

GammaC = 23.56 kN/cubic m
Conc.Strength Fc = 20700 kN/sq.m
Rein. Steel Fy = 413700 kN/sq.m
Surcharge Q = 23.9 kPa
Soil Height "H" = 6.1 m
Soil Height "h" = 1.4 m
(toe)

Tentative dimensions of structure
(as per above figure)

		SET 1	SET 2	SET 3	SET 4	SET 5	SET 6
A (m)	=	1.01	0.80	0.60	1.50	0.40	1.00
B (m)	=	2.45	2.16	2.00	2.75	2.13	1.50
D (m)	=	1.01	0.90	0.80	0.80	0.50	0.60
E (m)	=	0.50	0.45	0.40	0.50	0.25	0.25
F (m)	=	0.30	0.25	0.20	0.25	0.12	0.13
G (m)	=	4.27	3.66	3.25	5.00	2.90	2.88

Figure 3-18: Retaining Wall Design Lotus 1-2-3 Module

STEP 1

Calculation of Ka and Ka'for soil

Ka = 0.361

Ka' = 0.170

STEP 2

Computation of active earth pressure (Pa)

Pa = 95.79 kN

STEP 3

Computation of overturning stability

PART	Wt. OF PART (kN) (1)	ARM (m) (2)	MOMENT (kN.m) (1) $ (2)
1	200.09	2.13	426.20
2	35.93	1.13	40.42
3	9.34	1.34	12.49
4	40.71	1.44	58.62
5	7.12	1.29	9.20
6	3.11	1.32	4.09
Fv =	296.30 kN	Mr =	551.02 kN.m

Overturning Moment,Mo = 244.34 kN.M
Total horizontal , Fd = 95.79 kN
force

OVERTURNING SAFETY FACTOR (Mr/Mo) = 2.255095

Overturning safety factor should be greater than 2

STEP 4

Computation of sliding factor of safety

C' = .67 C2

C' = 23.56

Fr = 267.59 kN

Therefore,
SLIDING SAFETY FACTOR (Fr/Fd) = 2.793619
Sliding safety factor should be greater than 2

Figure 3-18: Retaining Wall Design Lotus 1-2-3 Module (Continued)

```
STEP 5
        Soil bearing pressure

          M  =    Mr - Mo  =   306.68
        (Net moment)
          x  =      M / Fv =      1.04 m from toe
        (distance from toe)
          e  =   (B/2) - x =      0.40 m
        (eccentricity)

        B / 6  should be greater than " e ",otherwise change dimensions
         B / 6 =          0.48    >         0.40



        Allowable soil pressure (qa)    =      900 kN/sq.m
        q      = Fv/B         =    102.88 kN/sq.m
        qmax   = q[1+(6e/B)] =    189.68 kN/sq.m
        qmin   = q[1-(6e/B)] =     16.08 kN/sq.m

        "qmax" and "qmin" should be less than "qa"

        REBAR DESIGN
        ------------
a) Wall Bending Moment

        @ Base
                          Mb    =    183.50 kN
                          Ru    =   1270.79 kN/sq.m
                          m     =     23.51
                          Row   =  0.003192
                     Area steel =     12.13 sq.cm/m

        @ Mid height

                          Mm    =     61.09 kN
                          Ru    =    615.63 kN/sq.m
                          Row   =  0.001515
                     Area steel =      5.76 sq.cm/m

b) Footing Bending Moments

        @ Toe section

                          X     =     69.44 kN/sq.m
                          V     =     55.04 kN
                          Vu    =     93.57 kN
                       Phi Vc   =    146.75 kN
```

Figure 3-18: Retaining Wall Design Lotus 1-2-3 Module (Continued)

"Phi Vc" should be greater than "Vu"

```
q1   =          113.33 kN/sq.m
q2   =           76.36 kN/sq.m
Mt   =           82.12 kN
Mw   =          139.60 kN
Ru   =          387.77 kPa
a    =           23.51
Row  =         0.00095
Area Steel =      5.69 sq.cm/m
```

@ Heel section

```
V    =           98.55 kN
Vu   =          137.96 kN
```

"Phi Vc" should be greater than "Vu", otherwise change the dimension "D".

```
Mh   =          123.18 kN
Mu   =          172.45 kN
Ru   =          479.04 kN/sq.m
a    =           23.51
Row  =         0.00117
Area Steel =      7.04 sq.cm/m
```

c) Horizontal steel

@ Wall

```
Area Steel =      2.64 sq.cm/m
```

@ Footing

```
Area Steel =      4.17 sq.cm/m
```

Figure 3-18: Retaining Wall Design Lotus 1-2-3 Module (Continued)

SELECTED DIMENSIONS ARE :

A (m)	=	1.00
B (m)	=	1.50
D (m)	=	0.60
E (m)	=	0.25
F (m)	=	0.13
G (m)	=	2.88

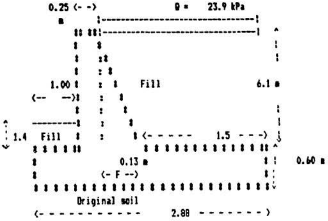


Figure 3-18: Retaining Wall Design Lotus 1-2-3 Module (Continued)

SET	OSF	SSF	(B/6)-e	qa-qmax	Phi Vc-Vu (for toe)	HPhi Vc-Vu (for feel)
SET1	4.53	4.15	0.55	742.36	247.03	26.29
SET2	3.49	3.71	0.31	709.28	240.80	26.98
SET3	2.86	3.43	0.14	676.13	232.63	11.72
SET4	6.50	4.83	0.96	803.23	74.33	-103.25
SET5	2.61	3.48	0.03	651.73	142.08	-127.57
SET6	2.26	2.79	0.08	710.32	53.18	8.79

Figure 3-19: Sensitivity Analysis Table for Retaining Wall Design

3.6. BIDDING

Estimating and bidding are two complementary tasks in construction, and most contractors do not distinguish between the two. However, the profit or loss on a project partly depends on the bid its lf. If the bid price is too high, the contractor loses the contract, but if the total price is too low, the contractor may win the bid but suffer a loss [11]. In order to improve the chances of winning the bid and making a reasonable profit, certain bidding procedures or strategies are applied to the bid. The bid strategies involve a study of market situations before finalizing a bid that provides enough profit and at the same time enhances the chances of winning a contract.

One of the most important factors in bidding strategy is the competitive situation. The probability of the success of a bid largely depends on the number of companies bidding for a particular project [11]. Bidding may be against unknown competitors against whom the contractor has never competed before, or it may be against known competitors against whom the contractor has competed before. Both of these situations have been applied on Lotus 1-2-3, and the strategies are discussed below.

3.6.1. Computer Module

As mentioned earlier, two types of competitors are faced by contractors in bidding. Accordingly, the contractor has to have enough foresight to get the contract through proper bidding strategies against both unknown and known competitors.

BIDDING STRATEGY AGAINST UNKNOWN COMPETITORS: The simplest case is when a contractor is facing one unknown competitor. If the contractor establishes the maximum markup, say, as 25% with a zero probability of getting the job, and the minimum markup as 0% with a probability of success of one, the relationship between the percentage markup and probability of success can be considered as linear [3]. This situation is represented both graphically and in a tabular form, by using Lotus 1-2-3, as shown in Figure 3-20. Expected profit is defined as the product of immediate profit, which is the contractors markup, and the probability of success [3]. As the bidding strategy assumes the best bid which shows maximum expected profit, a scan on the table (Figure 3-20) is done to find the maximum expected profit and its corresponding optimum percentage markup value. These two values are shown in Figure 3-20. If there is more than one competitor, the probability of success decreases markedly. A probabilistic approach [3] assumes that the chances of success (P) if there are two competitors would be P^2, with three competitors would be P^3, and so on. The same Lotus 1-2-3 module which is developed for the case of one unknown competitor is then extended to incorporate more than one competitor. A sample situation for three unknown competitors is shown in Figure 3-21. The maximum expected profit and its corresponding value of percentage markup is scanned by the Lotus 1-2-3 module and is shown in Figure 3-21. A graphical representation of the data is also shown in Figure 3-22.

The major advantage in using Lotus 1-2-3 is that in case of any change in the data, the Lotus 1-2-3 module automatically scans the new maximum expected

BIDDING STRATEGY AGAINST ONE UNKNOWN COMPETITOR

% MARKUP (M)	PROBABILITY OF SUCCESS (P)	EXPECTED PROFIT(%) (M)*(P)
0.0%	1.0	0.0%
5.0%	0.8	4.0%
10.0%	0.6	6.0%
12.5%	0.5	6.3%
15.0%	0.4	6.0%
20.0%	0.2	4.0%
25.0%	0.0	0.0%

Maximum expected profit = 6.3%

Therefor;

Optimum Percentage Markup = 12.5%

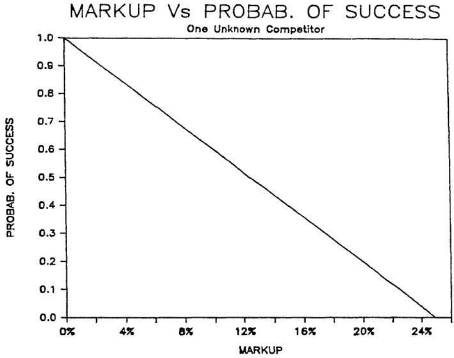


Figure 3-20: Bidding Strategy Against one Unknown Competitor

BIDDING STRATEGY: THREE UNKNOWN COMPETITORS

% MARKUP (M)	PROBABILITY OF SUCCESS [1 competitor] (P)	PROBABILITY OF SUCCESS [3 competitor] (P3)	EXPECTED PROFIT(%) (M)*(P3)
0%	1.0	1.0	0.0%
5%	0.8	0.5	2.6%
10%	0.6	0.2	2.2%
13%	0.5	0.1	1.6%
15%	0.4	0.1	1.0%
20%	0.2	.0	0.2%
25%	0.0	0.0	0.0%

Therefore

Maximum Expected Profit = 2.6%

Optimum Percentage Markup = 5.0%

Figure 3-21: Bidding Strategy Against Three Unknown Competitors

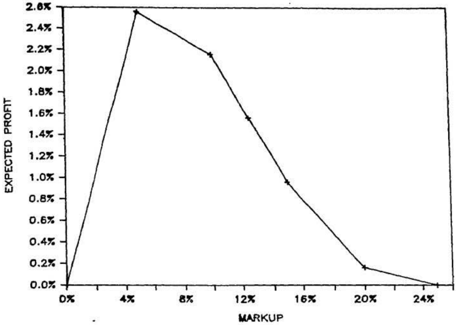


Figure 3-22: Expected Profit vs Markup-
Three Unknown Competitors

profit and its corresponding optimum percentage markup values. The graph representing the new values can then be drawn simply by pressing one key "F10" on the keyboard (for more detail see Lotus 1-2-3 manual under "/GRAPH" command).

BIDDING STRATEGY AGAINST KNOWN COMPETITORS: This approach is based on a contractor keeping records of his competitors' bidding patterns. This information is categorized into ratios between the contractor's own cost and his competitors bids [3]. This data enable the contractor to find a frequency of occurance for each interval, which can be used to obtain a probability of success. Figure 3-23 demonstrates the use of this technique for a contractor developing a strategy against one known competitor "A" [3].

This approach can be extended to handle any number of known competitors. A block diagram of a bidding strategy for more than one known competitor is shown in Figure 3-24. The values "1- P_0" (which is described in Figure 3-23) for each competitor are calculated by using the same table as shown in Figure 3-23. These values are then transferred to a separate table as shown in Figure 3-25. In Figure 3-25 expected profit is calculated by multiplying the markup by all the values of probabilities in which the contractor is lower than his competitors. Again, the maximum expected profit and its corresponding value of markup are scanned by Lotus 1-2-3, and are shown in Figure 3-25. The same information is also represented graphically in Figure 3-26.

BIDDING STRATEGY: ONE KNOWN COMPETITOR

COMPANY A'S BID RATIO TO CONTR'S COST (R)	FREQUENCY OF OCCURANCE (F)	PROBABILITY OF RATIO (Po=F/N) N=SUM OF F'S	PROBABILITY CONTRACTOR WAS LOWER (1- Po)	CONTR'S MARKUP (R-1)	EXPECTED PROFIT (1-Po)(R-1)
0.80	2	0.03	0.97	-20.00%	-19.49%
0.85	6	0.08	0.90	-15.00%	-13.48%
0.90	5	0.06	0.84	-10.00%	-8.35%
0.95	0	0.00	0.84	-5.00%	-4.18%
1.00	4	0.05	0.78	0.00%	0.00%
1.05	2	0.03	0.76	5.00%	3.80%
1.10	7	0.09	0.67	10.00%	6.71%
1.15	9	0.11	0.56	15.00%	8.35%
1.20	17	0.22	0.34	20.00%	6.84%
1.25	13	0.16	0.18	25.00%	4.43%
1.30	6	0.08	0.10	30.00%	3.04%
1.35	3	0.04	0.06	35.00%	2.22%
1.40	3	0.04	0.03	40.00%	1.01%
1.45	1	0.01	0.01	45.00%	0.57%
1.50	1	0.01	.00	50.00%	.00%

Maximum Expected Profit = 8.35%

Therefore

Optimum percentage markup = 15.00%

Figure 3-23: Bidding Strategy Against one Known Competitor

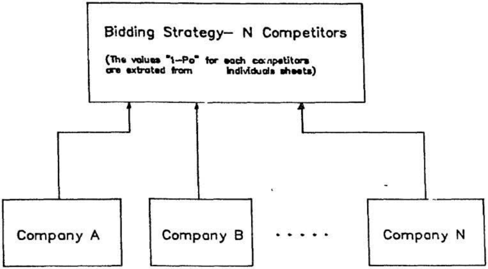


Figure 3-24: Block Diagram-Bidding Strategy Against More Than One Known Competitor

BIDDING STRATEGY: THREE KNOWN COMPETITORS

CONTRACTOR'S MARKUP (M)	PROBABILITY CONTR. WAS LOWER THEN			EXPECTED PROFIT
	COMPANY A	COMPANY B	COMPANY C	M*A*B*C
-20%	0.97	1.00	0.99	-19.30%
-15%	0.90	1.00	0.97	-13.08%
-5%	0.84	1.00	0.94	-3.93%
0%	0.84	0.99	0.90	0.00%
5%	0.78	0.87	0.84	2.87%
10%	0.76	0.82	0.72	4.48%
15%	0.67	0.68	0.57	3.90%
20%	0.56	0.26	0.42.	1.22%
25%	0.34	0.14	0.26	0.31%
30%	0.18	0.12	0.13	0.08%
35%	0.10	0.04	0.08	0.01%
40%	0.06	0.02	0.05	.00%
45%	0.03	0.00	0.02	0.00%
50%	0.01	0.00	0.01	0.00%

Maximum expected value = 4.48%

Therefore

Optimum Percentage profit = 10.00%

Figure 3-25: Bidding Strategy Against Three Known Competitors

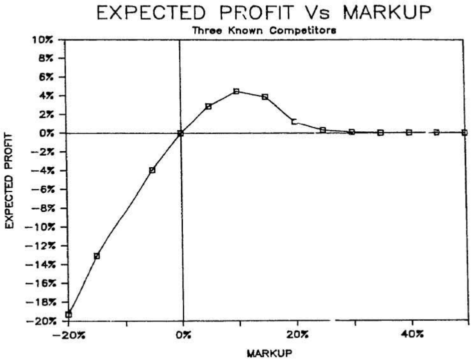


Figure 3-26: Expected Profit Vs Markup-
Three Known Competitors

3.7. PRELIMINARY CASH FLOW ANALYSIS

Preliminary cash flow analysis is carried out to determine the amount of money to be borrow for the project. This information is important because the loan finance charge is a job cost and must be a part of the estimate.

For most projects the cash flow builds up at the beginning, levels off and stays steady during the middle of the project, and gradually falls to zero at the end of the project. A typical cash flow diagram [11] is shown in Figure 3-27.

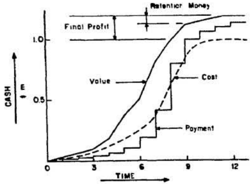


Figure 3-27: Typical Cash Flow Diagram

Three lines are plotted on the graph. The estimated value, which is the payment the contractor eventually receives from the owner, is plotted against time. The dotted line represents an actual amount of money or cost which the contractor spends on the project. This cost figure is obtained by subtracting the profit, which is fixed by the contractor, from the value. Generally, at the end of each month the contractor receives an interim monthly payment for the work that has been carried out during that month. These monthly payments are represented by a stepped line on the graph. The monthly cash flow lag between the amount of money spent by the contractor and the actual interim payments received from the owner, and is known as the monthly deficit. From the analysis of the monthly deficit the contractor finds the maximum amount of money required to finance the contract during the life of the project. The second part of the cash flow analysis is the computation of the retention money, the amount of money held back by an owner to ensure that the project is satisfactorily completed and maintained according to the conditions of the contract.

Based on the background described above, a module for cash flow analysis is developed on Lotus 1-2-3. The module is explained in the following section.

3.7.1. Computer Module

To use the module the contractor have to approximate the cash flow and profit percentage values based upon the previous jobs. A Lotus 1-2-3 solution for the cash flow problem is illustrated in Figure 3-28. The monthly cash flows are placed in the columns headed by (A) and (E). From this input information the computer calculates the monthly deficit, maximum deficit, and the retainage values. A cash flow diagram is also developed by using the graphic facility of the integrated package, and is shown in Figure 3-29.

By using the appropriate command and functions this program is easy to write. Most of the formulas are easily written by using the replicate command. In this application all of the input variables are subject to a high degree of variability. One of the advantage of this cash flow analysis module is that the

```
**********************
* CASH FLOW ANALYSIS *
**********************
```

(A) = Value of work put in place

(B) = Cumulative value of work put in place

(C) = Cumulative profit [% profit * (B)]

(D) = Actual amount of money spent [(B) - (C)]

(E) = Interm monthly payment

(F) = Deficit [(D) - (E)]

Profit (%) = 15.00%

MONTH	(A)	(B)	(C)	(D)	(E)	(F)
1	$26,005	$26,005	$3,901	$22,104	$0	$22,104
2	$60,000	$86,005	$12,901	$73,104	$25,000	$48,104
3	$76,000	$162,005	$24,301	$137,704	$90,000	$47,704
4	$75,000	$237,005	$35,551	$201,454	$130,000	$71,454
5	$73,000	$310,005	$46,501	$263,504	$190,000	$73,504
6	$68,000	$378,005	$56,701	$321,304	$250,000	$71,304
7	$68,000	$446,005	$66,901	$379,104	$380,000	($896)
8	$66,000	$512,005	$76,801	$435,204	$440,000	($4,796)
9	$43,400	$555,405	$83,311	$472,094	$500,000	($27,906)
10	$21,100	$576,505	$86,476	$490,029	$510,000	($19,971)
11	$0	$576,505	$86,476	$490,029	$515,000	($24,971)
12					$576,505	

MAXIMUM DEFICIT = $73,504

RETAINAGE VALUE = $61,505

Figure 3-28: Cash Flow Analysis Module

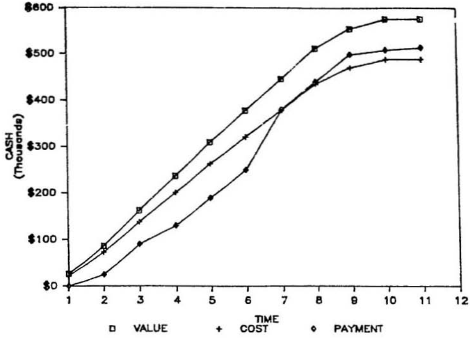


Figure 3-29: Cash Flow Diagram

input variables can be changed and the effects of the changes can be calculated instantaniously. The additional advantage is that a new cash flow diagram based on the new values can be obtained quickely. In this application the speed of recalculation and "what if" graphics are the major advantages of the integrated package. While it would normally take hours to recalculate and redraw graphs by normal procedures, Lotus 1-2-3 does it in seconds.

3.8. MATERIAL ACQUISITION

Material acquisition combines and integrates material take-off, purchasing, expediting, warehousing, receiving, and material distribution functions. These functions are too often performed without the proper integration. As a result, construction projects are burdened with reduced labor productivity, excessive surplus, and material shortages during construction.

Many organizations suffer from a lack of communication between the various groups responsible for material procurement and expediting. Often there is no established pattern for issuing information on the progress of delivery of materials. As a result, panic situations are apt to occur at every delay in arrivals. In order to overcome these problems, the following objectives should be met by material procurement procedure in the construction industry:

1. Determine whether materials would be available on time as required by the project construction schedule. This is necessary to establish physical feasibility of the project plan.

2. Produce instant information on the status of all materials at any time.

3. Eliminate construction delays resulting from lack of materials when needed.

4. Take into account surplus stock and minimize inventory levels.

5. Relate to different divisions whithin the organization.

6. Reduce panic situations and at the same time save management time by reporting only those cases that require action.

One such system to meet the above mentioned procedures is developed on Lotus 1-2-3 and described as follows:

3.8.1. Computer Module

The Lotus 1-2-3 material expediting system consists of two modules;

1. Input module, and

2. Output module

INFUT MODULE:- To use the Lotus 1-2-3 material expediting system all pertinent information on the project and on the necessary materials must be compiled. This information is then entered on three input sheets (Material information, Inventory Record, and Bill of materials), The use of these input sheets is explained by using an example of a building project.

The project is divided into work packages based on various types of materials used in the project. For each material the estimated time required for various operations like preparation of shop drawings, fabrication, shipping time, and so on, are entered as shown in Table 3-1. In the table, for example, concrete reinforcement is identified by the code number 0320; the unit of measure is in kilograms; and, as indicated, shop drawings are required for each order. The time for preparation of shop drawings is 10 days. The drawings require five days for review before they are sent to the architect for approval, which requires an additional five days. It takes 10 days to resubmit the drawings. There are 10 days for fabrication and another three days for shipping, whether from inventory or from a supplier. Finally, materials should be at the site three days before they are incorporated into the job so that they may be sorted. Since most of this information remains unchaged from one project to the next, the input is prepared only once. After periodic updating in the input the same can be used for

MATERIAL INFORMATION SHEET

1 Material code	2 Material	3 Unit of measure	4 Are shop drawings and/or samples req'd Yes/No	5 Time for preparation of shop drawings etc. T1	6 Time for review T2	7 Time for architect's review and approval T3	8 Time for resubmission T4	9 Time for fabrication T5	Time for shipping 10 From stock T6	Time for shipping 11 From supplier T7	12 Lead time
0311	Concrete forms	PCs.	No	-	-	-	-	3	3	3	3
0320	Concrete reinforcement	Kg	Yes	10	5	5	10	10	3	3	3
0410	Mortar	C.M	No	-	-	-	-	1	1	1	2
0421	Bricks	Ea.	No	-	-	-	-	5	5	10	10
0720	Insulation	S.M.	Yes	3	3	3	5	1	5	10	5
0820	Wood doors	Ea.	Yes	10	5	5	10	15	5	15	5
1521	W.S.pipe	L.M	No	-	-	-	-	1	5	15	5
1526	S & W pipe	L.M	No	-	-	-	-	1	5	15	5

Table 3-1: Material Information Sheet

subsequent projects. Depending on the type of work, the organization may have in stock a few or most of the materials it is using on a project. The next input in the module is to incorporate the physical inventory status.

An up-to-date physical inventory of stocked materials is important for material management operations. All data needed by the planner are included in the inventory record shown in Table 3-2. The name and code number of each material is given, as well as a description of the material (i.e., size, type, and so on) and the units in which the material is measured. Each line defines a material of a particular specification. In the example given, there are two types of concrete reinforcement (No. 3 and No. 7). There are 1000 kg of No. 3 rebar in stock and this quantity is kept within 500 and 1500 kg at all times. As only 300 kg of No. 7 rebar are in stock which is not with in the limits of maximum and minimum quantities to be kept in the stock all times, this deficit will be filled by 1200 kg on order and to be delivered by December 7, 1986.

Finally, a bill of materials which is a complete list of materials t. be used in a project is needed. A sample of such a sheet is shown in Table 3-3. As an example, consider the first entry in the table. The ma.erial code is 0421 indicating bricks, followed by the quantity of bricks, which is 20,000. The date of the first activity requiring the bricks is project day 54 (i.e., 54 workdays from the start of the project).

Above mentioned three tables constitute the input of the Lotus 1-2-3 material expediting system. Based on these inputs the system generates the output, which is a material procurement and expediting schedule.

INVENTORY RECORD

Material code no.	Material	Material description	Unit of measure	Quantity in stock	Will this be material restocked	Minimum quantity to be held in stock	Maximum quantity to be held in stock	Quantity on order	Delivery data
0311	Concrete forms	2x8 plywood panels	Pcs.	400	No				
0311	Concrete forms	2x10 plywood panels	Pcs.	350	No				
0320	Concrete reinforcement	No.3 by RL rebar	Kg	1000	Yes	500	1500		
0320	Concrete reinforcement	No.7 by RL rebar	Kg	300	Yes	500	1500	1200	07 Dec.86
0410	Mortar	Masonry cement	C.M.	600	Yes	100	1000		
0410	Mortar	Masonry sand	C.M.	400	Yes	100	1000		
0421	Bricks	Modular face brick buff	Ea.	5000	No				
0720	Insulation	33 mm roofmate insulation	S.M.		No				
0820	Wood doors	2-8 x 7 x 2 slab mah.	Ea.	6	Yes	4	10		
0820	Wood doors	3 x 7 x 2 plank oak	Ea.	10	Yes	4	10		
1521	W.S.pipe	50 mm copper pipe	L.M.	200	Yes	100	1000		
1526	S & W pipe	100 mm cast iron tyton joint	L.M.		No				

Table 3-2: Inventory Record Sheet

BILL OF MATERIALS

1 Work package no.	2 Material code no.	3 Material description	4 Quantity	5 Unit of measure	6 Start date of first activity requiring this material
4	0421	Modular face brick buff	20,000	Ea.	54
4	0410	Masonry cement	200	C.M	54
4	0410	Masonry sand	50	C.M	54
5	0720	3.75-cm. roofmate insulation	5,000	S.M.	67
1	1526	10-cm. Cast iron tyton joint pipe	200	L.M.	11
1	1521	5-cm. Copper pipe	200	L.M.	11
2	1526	10-cm. Cast iron tyton joint pipe	70	L.M.	36
2	1521	5-cm. Copper pipe	70	L.M.	36
8	0820	60-cm, 20-cm x 2-m x 45-mm slab mah. doors	15	Ea.	110
8	0820	90-cm x 2-m x 60-cm plank oak doors	2	Ea.	110

Table 3-3: Bill of Materials

OUTPUT MODULE:- The output module of the material expediting system establishes that materials required by the construction schedule should be available in time. The output module also provides complete information on the status of each material at any time as it progresses through the procurement process. The material procurement schedule is shown in Table 3-4.

Each entry from the bill of materials is included in the output table (Table 3-4) and the event times on which action must be taken to ensure arrival at the required time are also given. The total quantities of each kind of material to be ordered as well as a breakdown by work packages is given. As an example, Consider the wood doors shown in Table 3-4. Refering to the bill of materials and noting that there are two types of wood doors required in work package 8, fifteen of the first type (mahogany) and two of the second type (oak). As a first step, the inventory record is checked to see if these quantities are in stock. Therefore, in the column "Quantity from stock" per work package (column 8, Table 3-4) 6 and 2 are entered, respectively. The quantity from supplier per work package (column 9, Table 3-4) then becomes nine(15 - 6) of the first and none of the second. Both of these entries are for work package 8. The total quantity from supplier (column 6, Table-4) and total quantity from stock are 9 and 8 (6 + 2), respectively, which makes a total job quantity (column 4, Table-1) of seventeen (8 + 9) wood doors.

In order to calculate the data on which action must be taken, the activity start (column 6) given on the bill of material (Table 3-3) and the time required for each operation in the procurement process given on the materials information sheet (Table 3-1) are used. For instance, note that wood doors (Table 3-3) are required on project day 110. First, the required delivery date (column 16, Table 3-4) is obtained by subtracting the lead time (column 12, Table 3-3) of five days from 110. The day on which they must be shipped from the source, either supplier or stock, is calculated by subtracting the required shipping times (columns 10 and 11, Table 3-1) from the delivery date. Thus shipping dates of 90 (105 - 15) for the stock are obtained.

Since all the shop drawings for a certian item would probably be made and approved at one time, the earliest shipping date is taken (in this case day 90), and the time necessary for fabrication (15 days) is subtracted. Thus the date on which the drawings are received back from the architect [day 75 (90 -15)] is obtained. The day on which the drawings are to be returned for corrections is found by subtracting the time for re-submission (Table 3-1) from the date on which they are returned from the architect (75 - 10 = 65). The time needed to obtain approval from the architect is five days (Table 3-1) which is deducted from the previous date, to get day 60 (65 - 5). The date for receiving shop drawings is this date minus the review time (60 - 5 = 55). Finally, the time for preparation of shop drawings is subtracted (Table 3-2) from this date to get the order/expedit date (day 45), which is the date on which the order must be placed in order to ensure that the doors are delivered on day 105.

The negative entries under columns 10 and 15 for S & W pipes, indicate that the pipes cannot be supplied in time. If the activity has a float to accommodate this negitive value, there will not be any problem. If not,

MATERIAL PROCUREMENT SCHEDULE

1	2	3	4	5	6	Quantity per work package			10	11	12	12A	13	Shipping date		16
						7	8	9						14	15	
Material code no.	Material	Unit of measure	Total job quantity	Total quantity from stock	Total quantity from supplier	Work package no.	Quantity from stock	Quantity from supplier	Order/ expedit date	Receive shop drawings and/or samples	Submit to architect for approval	Return for correction	Return back from architect	From stock	from supplier	Delivery date
0410	Mortar	C.M.				4	200							51		52
0410	Mortar	C.M.				4	50							51		52
0410	Mortar	C.M.	250	250	-	-	-	-	51	N/A	N/A	N/A	N/A			
0421	Bricks	Ea.				4	5,000	15,000						39	34	44
0421	Bricks	Ea.	20,000	5,000	15,000	-	-	-	29	N/A	N/A	N/A	N/A			
0720	Insulation	S.M.				5	-	5,000							52	62
0720	Insulation	S.M.	5,000		5,000				37	40	43	46	51			
0820	Wood doors	Ea.				8	6	9						100	90	105
0820	Wood doors	Ea.				8	2	0						100	0	105
0820	Wood doors	Ea.	17	8	9				45	55	60	65	75			
0521	W.S.pipe	L.M				1	200	0						1	0	6
0521	W.S.pipe	L.M				2	0	70						0	16	31
0521	W.S.pipe	L.M	270	200	70				1	N/A	N/A	N/A	N/A			
0526	S & W pipe	L.M.				1	0	20						0	-9	6
0526	S & W pipe	L.M.				2	0	70						0	16	31
0526	S & W pipe	L.M.	270	0	270				-10	N/A	N/A	N/A	N/A			

Table 3-4: Material Procurement Schedule

appropriate action for obtaining the materials in time will be necessary. If there is no other alternative but to change the schedule, the material status sheet should be updated accordingly.

The material procurement schedule gives the project expediter information necessary to keep track of each material to be used in the project. When he receives word that the delivery of a material is falling behind schedule, he can check the material procurement schedule, determine whether the delay will affect the delivery date, and if necessary, revise the schedule.

The material expediting system discussed in this section is representative of other systems to meet similar requirements. Such a system is a very useful tool for construction management. Briefly, the advantages of using this system are the following:

1. The materials can be obtained as required by the construction schedule.

2. The material in stock can be used efficiently.

3. The lack of communication that can result in panic situations can be eliminated.

4. The system is very suitable for an integrated package application because of its flexible format.

3.9. MANAGEMENT CONTROL SYSTEM

The management control system is the co-ordinated function of estimating, cost control, and scheduling. Specialized software are available for such co-ordinated study by mainframe and minicomputers. For microcomputers some software are also available but are very expensive, and not flexible enough to meet the in-house procedures of the contractors. At present some of the microcomputers are sold with two packages included in the original purchase price of the equipment, and some of the newest hardware have these programs in their ROM (Read Only Memory) and can be accessed whenever the computer is on [35]. These two software packages are; integrated packages and time management programs. If properly planned and designed these two software packages can be chained together producing a valuable tool for a management control system. The results obtained by chaining these software can be comparable to the results derived from more expensive specialized software designed for mainframe, mini, or microcomputers.

By chaining the Lotus 1-2-3 and the Managemint software packages a management control system is developed and is described as follows.

3.9.1. Computer Module

A flow diagram of a management control system is illustrated in Figure 3-30. As mentioned earlier the two software used for implementing the system are Lotus 1-2-3 and the time management programme Managemint. Lotus 1-2-3 is used for quantity take-off, organization of data, pricing, and report generation. The scheduling data produced in the Lotus 1-2-3 module is then further utilized

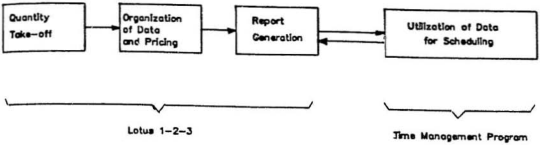


Figure 3-30: Flow Diagram- Management Control System

by the time management program for scheduling the project activities. Each step in the formation of the management control system is explained in the following paragraphs. The discussion emphasizes the methodology of developing a management control system rather than presenting a complete system.

QUANTITY TAKE-OFF: The Lotus 1-2-3 application is useful in quantity take-off. The formulas, functions and titles entered on the sheet for quantity take-off form a template that can be used repeatedly to perform similar calculations for any project. An example of quantity take off is shown in Figure 3-31. In this quantity take-off sheet the volume of a foundation wall is calculated. The quantity take-off sheet shown in Figure 3-31 is very similar to the manual estimating forms, except that the calculations of foundation wall volume are performed automatically as soon as the numbers are entered on the sheet. The

QUANTITY TAKE-OFF SHEET

DESCRIPTION	LENGTH (m)	HEIGHT (m)	THICK (m)	NUMBER	VOLUME (cu.m.)
Wall,NW	27.78	3.00	0.20	1	16.67
	59.25	5.00	0.08	1	23.70
	31.12	2.50	0.10	1	7.78
	35.56	2.50	0.10	1	8.89
	16.00	2.50	0.10	1	4.00
	6.17	3.00	0.10	1	1.85
Wall,EW	49.38	3.00	0.08	1	11.85
	4.63	3.00	0.08	1	1.11
	6.17	3.00	0.08	1	1.48
Wall,,SE	30.85	3.00	0.08	2	14.81
Wall,NE	61.75	3.00	0.08	1	14.82
	21.63	3.00	0.08	1	5.19
			Total Concrete Volume		112.15 cu.m.

Figure 3-31: Quantity Take-off Sheet

sheet can be used for any project that has foundation walls. Once the quantities are calculated in the spreadsheet the data is organized with the help of the information management facility of the integrated package. This organized data is then further used to price the project, and prepare various types of reports such as scheduling reports, estimating and cost control reports.

ORGANIZATION OF DATA: Most of the commercially available integrated packages have the capability of information management. This information management facility can be used to perform the useful and necessary functions of mentaining files, manipulating and sorting data, generating reports and performing calculations between different stored files.

With the information management facility of Lotus 1-2-3, files can be designed to keep information about the cost of labor, equipment and materials necessary to monitor project activities. Data on all activities can be calculated as soon as the quantities of work are transferred from the spreadsheet take-off files. An example of a data base management file is shown in Figure 3-32. The labor, material, and equipment information are transferred from the data base files (as shown in Figure 3-10) and the quantities are transferred automatically from the take-off files by using the appropriate commands. Based on this information pricing is done automatically by Lotus 1-2-3. The data organization files are then updated for the actual cost of work in place, and the variance between the actual cost of work in place and its estimated cost is automatically calculated for cost control.

ORGANIZATION OF DATA AND PRICING

CSI DIV	ACTIVITY DESCRIPTION	NO	QUANT.	UNIT	CREW	DAILY OUTPUT	CREW COST/DAY	EST.LAB. COST	MATERIAL UNIT COST	UNIT	EST.MAT. COST	EQPT COST	TOTAL ACT.COST
3	pour fnd. wall conc.	7	112.2	c.m	C-4	60	4,050	7570	60	c.m	6,729		$14,299

Figure 3-32: Data Organization Sheet

The main objective of organizing the data, as shown in Figure 3-32, is to use this data for generating various types of reports. A well designed data organization file can generate reports that are useful in many management decisions and tasks. The estimating report, in Figure 3-33, the scheduling report in Figure 3-34, and the cost control report in Figure 3-35 were generated from the data organization file. The estimating report sorts the cost information based on division of work, the scheduling report prepares information for scheduling activities and resources, while the cost control report keeps track of the different costs of the project.

ESTIMATING REPORT

CSI DIV	ACTIVITY DESCRIPTION	ESTIMATED LAB COST	ESTIMATED MATR. COST	ESTIMATED EQPT COST	TOTAL ESTIMATION
2	Excavate footers	2,000		600	$2,600
	Rough grading	1,720		1,367	$3,087
				total	$5,687
3	Form fnd walls	1,879	1,980		$3,859
	Poor floor slab	15,025	46,700	890	$62,615
	Poor fnd wall concr	7,570	6,729		$14,299
	Poor footers	925	785		$1,710
	Rebars footers	426	635		$1,061
	Rebars for fnd wall	1,425	2,345		$3,770
				total	$87,314
				TOTAL COST	$93,001

Figure 3-33: Estimating Report

SCHEDULING REPORT

NUMBER	ACTIVITY DESCRIPTION	DURATION (DAYS)	CREW	EQUIPMENT
1	Rough grading	4	G-12	DB,TR
2	Excavate footers	3	G-12	BK,TR
3	Rebars footers	2	R-01	
4	Pour footers	1	C-03	
5	Form fnd walls	8	C-12	
6	Rebars for fnd wall	7	R-01	
7	Pour fnd wall concr	2	C-4	
8	Pour floor slab	8	D-08	mech float

Figure 3-34: Scheduling Report

COST CONTROL REPORT

NUMBER	ACTIVITY DESCRIPTION	TOTAL ESTIMATE	TOTAL ACTUAL	VARIANCE ($)	VARIANCE AS A %
1	Rough grading	$3,087	$4,050	963	23.78%
2	Excavate footers	$2,600	$2,347	-253	-10.78%
3	Rebars footers	$1,061	$1,091	30	2.75%
4	Pour footers	$1,710	$1,600	-110	-6.88%
5	Form fnd walls	$3,859	$3,900	41	1.05%
6	Rebars for fnd wall	$3,770	$3,500	-270	-7.71%
7	Pour fnd wall concr	$14,299	$14,589	290	1.99%
8	Pour floor slab	$62,615	$64,780	2165	3.34%

Figure 3-35: Cost Control Report

SCHEDULING: Many microcomputer programs are available for time management and construction scheduling operations. Most of these programs use the critical path method for scheduling project activities, determining the critical ones, calculating their early and late start dates, early and late finish dates. Most time management programs have the ability to draw bar charts and to sort activities according to some predetermined criteria. A sample result of a time management program is shown in Figure 3-36. The input to the program was the data generated by Lotus 1-2-3 in Figure 3-34. Time management programs need not be very sophisticated if used with integrated packages. The schedule, resulted from the CPM analysis, could be easily incorporated in an integrated package to be sorted for cost control, resource scheduling and other important functions required for management control.

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Critical Path Analysis

ACT #	ACTIVITY NAME	DURATIONS EXPD/CALC		ERLST START	LATEST START	ERLST FINISH	LATEST FINISH	------- FLOAT ------ TOTAL	FREE	SAFETY
1	Rough grading	4/	4	0	0	4	4	0	0	0
2	Excavate footers	3/	3	4	4	7	7	0	0	0
3	Rebars footers	2/	2	7	7	9	9	0	0	0
4	Pour footers	1/	1	9	9	10	10	0	0	0
5	Form fnd. walls	8/	8	10	15	18	23	5	0	5
6	Rebars for fnd. wall	7/	7	10	10	17	17	0	0	0
7	Pour fnd. wall concr	2/	2	18	23	20	25	5	0	5
8	Pour floor slab	8/	8	17	17	25	25	0	0	0

Figure 3-36: Project Schedule from "ManageMint" Software

3.10. EQUIPMENT REPLACEMENT ANALYSIS

Equipment replacements are always a dilemma for the contractors and the companies having large fleets of equipment. Modern technology has created obsolescence, and this factor has shortened the economic life of a machine so that it is usually less than its physical life, which is the age at which the machine is exhausted and can no longer produce. It is essential, therefore, to have a suitable equipment replacement policy. The replacement policy may be viewed as consisting of a decision at the end of each year about whether or not to replace the existing equipment. The decision to replace now or later depends on some sort of economic analysis and in all economic analysis several factors or variables are involved in predicting a reasonable conclusion. Inflation rate, borrowing interest rate, and taxes are some examples of these variables. The final result or conclusion is dependent on or sensitive to each one of these variables. In order to have an in depth economic study, each variable is varied within the reasonable limits, referred to as a sensitivity analysis. When the number of variables becomes large and sensitivity analysis is intended to be done, the change of each of the different variables for a wide range of selection makes the process extremely arduous and lengthy. As a result, it has become a customary to use computers for fast and accurate results for such a massive job.

A microcomputer using an integrated package can perform sensitivity analysis very well. To show the effectiveness of the use of an integrated package for equipment replacement analysis, a module is developed on Lotus 1-2-3. and is described as follows.

3.10.1. Computer Module

A large off-highway truck is considered for replacement by a new model with the same capacity. The existing equipment is termed "defender" and the tentative replacement is termed "challenger". The defender is considered to have a service life of one year, and the challenger has five years of useful life. The contractor wants to know whether the replacement is justified.

The basic solution procedure for an equipment replacement module is essentially a four step algorithm. The first step is to determine the annual cost of the defender. The second step in the basic solution algorithm is to determine the equivalent cost of the challenger for the next (1,2,3.... years) ownership periods without considering the tax savings. The third step is to incorporate the tax savings in the equivalent annual ownership cost of the challenger. And the final step is the selection of the more economic equipment, the one with the lowest annual cost. The equipment are compared on the annual cost bases, because of the different service lives.

The projected ownership and operating expenditures required as input are shown in Figure 3-37. The data is stored in the two columns under the headings as defender and challenger.

The first step, which is to determine the annual ownership cost of the defender, is shown in Table A (Table A is in Figure 3-37). As the defender is considered to have a service life of one year, its annual costs are only the operating cost with the salvage value deducted.

The second step in the algorithm is to determine the equivalent annual cost of the challenger for the ownership period, without considering the tax savings. Calculations to determine the net expenses the challenger will incure if it is retained for a ownership period, which is 5 years in this particular example, are illustrated in Table B (Table B is in Figure 3-37). All expenditures in the Table B are in terms of current dollars, the finance payments are deflated for the annual inflation rate (which is 8% in this example). This is based on the assumption that the equipment loan is being repaid with inflated dollars. To compare the productivity and/or availability of the challenger to that of the defender. simple indices are used as shown in column 7 and 8 of Table B. The adjusted net expenses (column 10 of Table B) are produced by dividing the net expenses by the combined indices. At this stage if the tax savings are to be included , the module incorporates the third step of the basic solution algorithm which is explained later. Otherwise, the annual cash flow of the challenger will be converted into the present worth and the present worth value will be converted into the equal annual cash flow, which will be compared with the annual cost of the defender.

The third step in the basic solution algorithm is to incorporate the tax savings in the annual ownership costs of the challenger. The amount to be written off in taxes each year is the interest paid on the loan plus the depreciation amount. For depreciation, three methods are incorporated in the module. The calculations for an assumed five years challenger ownership period including tax advantages are illustrated in Table C (Table C is in Figure 3-37). Depreciation, interest, and tax credit savings are computed and deducted from the basic net expenses as shown in Table C.

The economic comparison of the equipment is located at the bottom of the Figure 3-37, highlighted by asterisks. The results for the given input data implie that the challenger is the better investment. However, to have confidence in this selection a sensitivity analysis is performed.

Sensitivity analysis can be easily done by Lotus 1-2-3. When the values of variables are changed Lotus 1-2-3 will automatically recalculate the annual cost for both defender and challenger. The user can change just one variable or many, and can see their effects on the annual cost of the equipment. By utilizing the Lotus 1-2-3's keyboard macro facility a sensitivity analysis table is generated, which is shown in Table 3-5. From the table it is clear that for varying tax rates, interest rates, prime rates and inflation rates the module calculates the annual costs of both defender and challenger. This sensitivity analysis can be displayed graphically. As an example, for varying interest rates and tax rates, the annual costs of both defender and challenger are shown in Figure 3-38 and Figure 3-39 respectively.

The above example explained the use of an integrated package for an equipment replacement problem. In this computer module complex mathematical expressions and methods of calculus have been avoided, by performing all calculations in tabular format. Incorporating the module's logic into an integrated package allows the module user to rapidly perform replacement investigations aud "what if" comparisons graphically.

EQUIPMENT REPLACEMENT MODEL

	YR	DEFENDER	CHALLENGER
MODEL NO.			
PRICE			$250,000
SALVAGE	YR		
	1	$40,000	
	2		
	3		
	4		
	5		
LIFE		1	5
YEARS FINANCED		0	5
FINANCE RATE (%)			16.00
COST OF CAPITAL (%)			15.00
INFLATION RATE (%)		8.00	8.00
TAX RATE (%)		48.00	48.00
MAINTENANCE COSTS	YR		
	1	$140,000	$32,000
	2	$0	$84,000
	3	$0	$110,000
	4	$0	$145,000
	5	$0	$168,000
OPERATING HOURS	YR		
	1	3,100	4,500
	2		4,200
	3		3,900
	4		3,700
	5		3,500
PRODUCTIVITY INDEX			1
FUEL COST ($/GAL)		$1	$1
FUEL CONSUMPTION(GAL/HR)		17.10	15.10
FUEL COST ($/HR)		$21	$18
OPERATOR COST ($/HR)		$23	$23
FUEL COST (YR)	YR		
	1	$63,612	$81,540
	2	$0	$76,104
	3	$0	$70,668
	4	$0	$67,044
	5	$0	$63,420

Figure 3-37: Equipment Replacement Module

OPERATING HOUR	YR		
INDEX	1	1	1.45161
	2		1.35484
	3		1.25806
	4		1.19355
	5		1.12903
OPERATOR COST	YR		
	1	$72,540	$105,300
	2		$98,280
	3		$91,260
	4		$86,580
	5		$81,900

DEFENDER ANNUAL COST CALCULATIONS

TABLE A

DEFENDER OWNERSHIP COST FOR THE
NEXT ONE YEAR OWNERSHIP PERIOD

YR	FINANCE PMNT.	M+F+D COSTS	SALVAGE	NET EXPENSES
1		$276,152	$40,000	$236,152
2		0	0	0
3		0	0	0
4		0	0	0
5		0	0	0

DEFENDER NET ANNUAL COST $236,152

CHALLENGER ANNUAL COST CALCULATIONS

PRICE		$250,000
FINANCE RATE =		0.16
YEARS =		5
FINANCE PAYMENT ANNUAL =		$76,352
INFLATION RATE =		0.08
FINANCE PAYMENTS DEFLATED		
	YR	
	1	$70,697
	2	$65,460
	3	$60,611
	4	$56,121
	5	$51,964

Figure 3-37: Equipment Replacement Module (Continued)

TABLE B

CHALLENGER OWNERSHIP COST CALCULATIONS WITHOUT TAX CONSIDERATIONS

YR	FUEL	OPERATOR	MAINTENANCE	FINANCE PMNT DEFLATED	SALVAGE
	(1)	(2)	(3)	(4)	(5)
1	$81,540	$105,300	$32,000	$70,697	$0
2	$76,104	$98,280	$84,000	$65,460	$0
3	$70,668	$91,260	$110,000	$60,611	$0
4	$67,044	$86,580	$145,000	$56,121	$0
5	$63,420	$81,900	$168,000	$51,964	$0

YR	NET EXPENSE	PRODUCTIVITY INDEX	OPERATING HR. INDEX	COMBINED INDEX	ADJESTED NET EXPENSE
	(1)+(2)+(3)+(4)-(5)			(7)*(8)	(6)X(9)
	(6)	(7)	(8)	(9)	(10)
1	$289,537	1.00	1.45	1.45	$199,459
2	$323,844	1.00	1.35	1.35	$239,028
3	$332,539	1.00	1.26	1.26	$264,326
4	$354,745	1.00	1.19	1.19	$297,219
5	$365,284	1.00	1.13	1.13	$323,537

MODEL SOLUTION: INCORPORATING INCOM TAX CONSIDERATIONS

DEPERATION CALCULATIONS
SELECT DEPRECIATION METHOD BY PRESSING [Alt] AND [CODE] KEYS SIMULTANIOUSLY

CODE KEY	DEPRECIATION METHOD
A	STRAIGHT LINE
B	DECLING-BALANCE(GIVE APPL. RATE %)=
C	SUM OF YEARS DIGITS

YEAR	DEPRECIATION
1	$83,333
2	$66,667
3	$50,000
4	$33,333
5	$16,667

SELECTED DEPRECIATION METHOD IS SUM OF YEARS-DIGITS

Figure 3-37: Equipment Replacement Module (Continued)

TABLE C

CHALLENGER CASH FLOW INCLUDING TAX SAVINGS

YR	LOAN PAYMENT	YEAR END LOAN BALANCE	INTEREST (12)% INTR.	DEPRECIATION	DEP. + INTR.
	(11)	(12)	(13)	(14)	(15)
1	$76,352	$250,000	$40,000	$83,333	$123,333
2	$76,352	$213,648	$34,184	$66,667	$100,850
3	$76,352	$171,479	$27,437	$50,000	$77,437
4	$76,352	$122,563	$19,610	$33,333	$52,943
5	$76,352	$65,821	$10,531	$16,667	$27,198

YR	TAX SAVED TAX % (15)	DEFLATED TOTAL SAVINGS	ADJUSTED NET EXPENSE (10)-(17)
	(16)	(17)	(18)
1	$59,200	$54,815	$144,644
2	$48,408	$41,502	$197,525
3	$37,170	$29,506	$234,819
4	$25,413	$18,679	$278,540
5	$13,055	$8,885	$314,652

COST OF CAPITAL = 0.15

NET PRESENT COST = $745,226

NET ANNUAL COST = $227,599

\##

DEFENDER ANNUAL COST = $236,152

CHALLENGER ANNUAL COST = $227,599

\##

Figure 3-37: Equipment Replacement Module (Continued)

SENSITIVITY ANALYSIS TABLE				
FACTOR		VALUE	DEFENDER ANNUAL COST	CHALLENGER ANNUAL COST
	1-	50.00	$236,152	$226,154
TAX	2-	40.00	$236,152	$227,599
RATE	3-	30.00	$236,152	$240,603
(%)	4-	20.00	$236,152	$247,828
	5-	0.00	$236,152	$262,277
	1-	18.00	$236,152	$239,067
INTEREST	2-	17.00	$236,152	$233,300
RATE	3-	16.00	$236,152	$227,599
(%)	4-	15.00	$236,152	$221,965
	5-	14.00	$236,152	$216,397
	1-	16.00	$236,152	$221,596
PRIME	2-	15.00	$236,152	$227,599
RATE	3-	14.00	$236,152	$233,853
(%)	4-	12.00	$236,152	$247,171
	5-	11.00	$236,152	$254,265
	1-	9.00	$236,152	$227,050
INFLATION	2-	8.00	$236,152	$227,599
RATE	3-	7.50	$236,152	$227,884
(%)	4-	7.00	$236,152	$228,176
	5-	5.00	$236,152	$229,418

Table 3-5: Equipment Replacement- Sensitivity Analysis Table

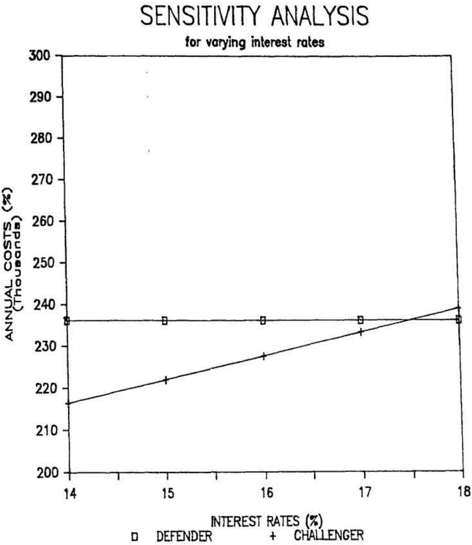

Figure 3-38: Sensitivity Analysis for Varying Interest Rates

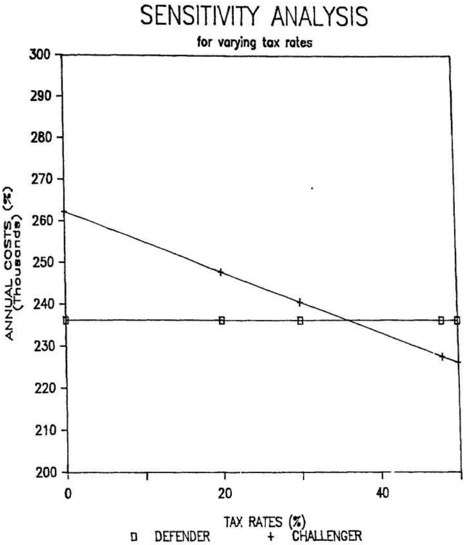

Figure 3-39: Sensitivity Analysis for varying Tax Rates

3.11. OWNING AND OPERATING COSTS OF CONSTRUCTION EQUIPMENT

Construction equipment plays a vital role in project construction both from completion time and cost point of view. Since the cost of using equipment runs between 20 to 30 percent of the job cost on some construction projects such as highways, the selection of the proper size and type of equipment is of prime importance. The two main aspects that need consideration when selecting construction equipment are the productivity of the equipment and the costs associated with owning and operating the equipment. The approach most often used to measure machine performance is the simple equation [31]:

$$\text{Top machine performance} = \frac{\text{Lowest possible hourly cost}}{\text{Highest possible hourly productivity}}$$

Generally, the productivity of the equipment can be obtained from the information provided by the equipment manufacturers, but the hourly costs of owning and operating the equipment can not be obtained from the manufacturers' literature since these costs vary widely depending upon many factors such as the operating conditions, depreciation policy, interest charges. This aspect of construction equipment is selected for computerization because of the changing nature of the factors which affect the owning and operating costs.

In the case of owning and operating equipment for construction work, there are two well-defined categories of time which should be recognized for cost purposes: the time when the equipment is operating and actually producing or contributing to the finished product, and the time when the equipment is owned but not operating. Thus, there are parts of the total equipment cost that are generated during operating time, called equipment operating costs, and costs occurred during the idle time called owning costs. Therefore, it can be said that the operating costs depend on the actual production time of the equipment, and that the owning costs depend on the passage of calendar time.

A computer module using an integrated package on microcomputer is developed for estimating the hourly costs of construction equipment. The method used in the program for estimating these costs is the result of a careful selection of published data on the subject, and especially, the guidelines and recommendations given by Nunnally [28]. The different tables that are included in the program were obtained from this book because they were found to be adequate for estimating operating costs of construction equipment. The method is fully explained in Appendix-D.

It is expected that this program will be found useful by all levels in construction organizations and that it can be used for application in real life situations.

3.11.1. Computer Module

The computer module for calculating owning and operating costs is designed to enable the user to work with it without having to refer to any book or manual. This module is structured as a menu driven on the Lotus 1-2-3 integrated package. The module starts with the master menu as shown in Figure 3-40. Items of the Master Menu are explained as follows.

```
################################################################
HOURLY CONSTRUCTION EQUIPMENT COST COMPUTATION MODEL
################################################################

NO              MASTER MENU
----            -----------
 A        INPUT DATA

 B        CALCULATIONS OF EQUIPMENT OWNING COSTS

 C        CALCULATIONS OF EQUIPMENT OPERATING COSTS

 D        SUMMARY OF EQUIPMENT OWNING AND OPERATING COSTS

  SELECT THE MENU ITEM BY PRESSING [Alt] AND [NO] KEYS
  SIMULTANIOUSLY.

  FOR RETURNING BACK TO MASTER MENU PRESS [Alt] AND [M] KEYS
  SIMULTANIOUSLY.
```

Figure 3-40: Master Menu- Equipment Owning & Operating Costs

The first item on the master menu is the Input Data sheet, which is illustrated in Figure 3-41. Input data is categorized under the following headings:

A- Equipment Characteristics

B- Equipment Owning Costs Inputs

C- Equipment Operating costs Inputs

D- Charges for the Equipment operator.

Although each item in the input data sheet is self explanatory, some items are explained for illustration.

The description of the equipment being analyzed may consist of any number of alphanumeric characters. The equipment salvage value may be selected as a percentage of the total cost of the equipment or a desired value may be provided. There are two options for the equipment working hours. This value may be a constant value for the entire life of the equipment, or a variable value may be selected for each year of the equipment life.

For equipment owning cost inputs three methods of depreciation are incorporated in the computer module. The user can select any one from these three depreciation methods. For this purpose the keyboard macro facility of Lotus 1-2-3 is utilized.

Two options are provided for each item of the operating cost inputs. Option 1 is based on the principle of contractors keeping records of these items from the previous jobs. Option 2 is designed based on the published data on the subject. If option 2 is chosen, the user has to select the values of various factors from the tables provided in the module (Figure 3-41). Detailed calculations of equipment owning and operating costs are given in Appendix-D.

Once the input data have been entered, the user will have the choice of seeing equipment owning and operating costs calculations or a summary of total equipment owning and operating costs. These operations can be selected from the master menu. Equipment owning and operating cost calculations of the selected example are illustrated in Figure 3-42 and Figure 3-43 respectively. The summary of the owning and operating costs is shown in Figure 3-44.

One of the advantage of using Lotus 1-2-3 in this type of analysis is its capability of representing the numbers graphically. The graphical representation of the summary of the equipment costs is shown in Figure 3-45. When the input parameters are changed, the equipment costs can be analyzed graphically. For example, by changing the depreciation method, total equipment costs will be changed. The new equipment costs can be seen by simply pressing one function key (F10) on the keyboard. This new situation is presented in Figure 3-46. This visual sensitivity analysis can be done by changing one or more input parameters simultaniously.

This computer module is based upon collection of the information that is found to be the most suitable and adequate for estimating owning and operating costs of construction equipment. The computer module is not only directed towards people with an extensive background in construction equipment analysis, but also to practitioners who have never been exposed to construction equipment economics. The advantages of using an integrated package Lotus 1-2-3 are that the tables provided in the module can be changed according to the organization's own data, sensitivity analysis can be performed with ease, and the results can be displayed graphically.

INPUT DATA

A- EQUIPMENT CHARACTERISTICS

```
1- Equipment Description                      =
2- Equipment Total Cost              ( $ ) =$224,000
3- Equipment Useful Life           (Years) =     5
4- Equipment Salvage Value :
       OPTION 1:  % Of Equipment Total Cost
                                (Input %) =
       OPTION 2:        Salvage Value ( $ )= $30,000
5- Cost of new set of tires           ( $ )= $20,000
     (if not applicable to this
      equipment enter 0)
6- Working Hours Per Years :
       OPTION 1:            Constant value
                            ( Hours/Year ) =    2000
       OPTION 2:        Variable Values

                  YEAR          WORKING HRS.
                    1
                    2
                    3
                    4
                    5

7- Equipment Brake Horsepower ( HP )      =     330
```

B- EQUIPMENT OWNING COSTS INPUTS

```
1- Method of depreciation :
                CODE      DEPRECIATION METHOD
                 X         The Straight Line
                 Y         The Double Declining Balance
                 Z         The Sum of the Years Digits
       Select the depreciation method by pressing
       [Alt] and [CODE] keys simultaniously

2- Investment Costs
       a. Interest Charge  ( % ) =      10
       b. Tax Charge       ( % ) =       5
       c. Insurance Charge ( % ) =       7
       d. Storage Charge   ( % ) =       5

            Investment rate %   =      27
              (a+b+c+d)
```

Figure 3-41: Input Data for Equipment Costs

C- EQUIPMENT OPERATING COST INPUTS

1- Fuel Consumption Costs

a)

OPTION 1: Fuel Consumption is known
(Gal/Hr.) =

OPTION 2: Estimation suggested by program
Select the equipment load factor
(from the Table.1 given below) = 0.6

TABLE 1

EQUIPMENT LOAD FACTORS

Type of Equipment	Load Conditions Low	Average	High
Clamshell and Dragline	0.40	0.50	0.60
Cranes	0.30	0.40	0.50
Graders	0.45	0.60	0.85
Loader, Track	0.50	0.75	0.90
Loader, wheel	0.45	0.60	0.85
Off-Highway truck	0.25	0.35	0.90
Scraper, elevating	0.50	0.65	0.85
Scraper, standard	0.45	0.60	0.50
Scraper, tandem	0.45	0.65	0.80
Shovel and hoe	0.50	0.60	0.70
Tractor, crawler	0.45	0.60	0.80
Tractor, wheel	0.50	0.65	0.85
Wagons	0.50	0.65	0.80

b)

- Cost of Fuel ($/Gal.) = 1.2
- Expected annual rate of increase in cost of fuel (%) = 10

2- Service Costs

OPTION 1: Hourly Service Costs known
($/Hr.) =

OPTION 2: Estimation suggested by program
Selected Service Factor
(from the Table.2 given below) = 0.33

Figure 3-41: Input Data for Equipment Costs (Continued)

TABLE 2	
SERVICE FACTORS	
Favorable conditions	0.2
Average conditions	0.33
Severe conditions	0.5

3- Costs of Major Repairs :

OPTION 1: Hourly Costs of Repairs known
($ / Hr.) =

OPTION 2: Estimation suggested by program
Selected Repair Factor
(from the Table.3 given below) = 0.9

TABLE 3

REPAIRS FACTORS

Type of Equipment	Load Conditions		
	Favorable	Average	Unfavor.
Crawler tractors	0.85	0.90	0.95
Graders	0.45	0.50	0.55
Off-Highway trucks	0.70	0.80	0.90
Scrapers	0.85	0.90	1.05
Track loaders	0.85	0.90	1.05
Wagons	0.45	0.50	0.55
Wheel loaders	0.50	0.60	0.75
Wheel tractors	0.50	0.60	0.75

4- Costs of Tire Replacements :

OPTION 1: Hourly Costs of Tire Replacement known
($ / Hr.) =

OPTION 2: Estimation suggested by program
Selected Expected Tire Life
(from the Table.4 given below - Hours) = 300C

Figure 3-41: Input Data for Equipment Costs (Continued)

TABLE 4			
TYPICAL TIRE LIFE (Hrs)			
Type of Equipment	Operating Conditions		
	Favorable	Average	Unfavor.
Dozers and loaders	3200	2100	1300
Motorgraders	5000	3200	1900
Scrapers	4000	3000	2300
Trucks and Wagons	3500	2100	1100

5- Tire Repairs Costs :

OPTION 1: Hourly costs of Tire Repairs known
($ / Hr.) =

OPTION 2: Estimation suggested by program
Percentage Selected (%) = 15

D- CHARGES FOR THE EQUIPMENT OPERATORS

Hourly Wages of Operator ($/Hr) = 16

Expected annual % rate of increase
in Operator's wages (%) = 10

IN ORDER TO RETURN TO MASTER MENU PRESS [Alt]
AND [M] KEYS SIMULTANIOUSLY

Figure 3-41: Input Data for Equipment Costs (Continued)

EQUIPMENT OWNERSHIP COSTS CALCULATIONS

1- Depreciation Costs :

-Selected depreciation method is Straight Line

END OF YEAR	DEPRECIATION	BOOK VALUE
0		$204,000
1	$44,797	$159,203
2	$44,797	$114,405
3	$44,797	$69,608
4	$44,797	$24,811
5	$44,797	$0

2- Investment Costs :

- Assuming the following charges :

Interest charge	10.00%
Taxes charge	5.00%
Insurance charge	7.00%
Storage charge	5.00%

Investment Rate 27.00%

END OF YEAR	INVESTMENT RATE	AVERAGE BOOK VALUE	INVESTMENT COST
1	27.00%	$181,601	$49,032
2	27.00%	$136,804	$36,937
3	27.00%	$92,007	$24,842
4	27.00%	$47,209	$12,747
5	27.00%	$12,405	$3,349

Figure 3-42: Equipment Owning Costs Calculations

EQUIPMENT OWNING COSTS (YEARLY)

END OF YEAR	DEPRECIATION COSTS	BOOK VALUE	INVESTMENT COSTS	TOTAL COSTS
0	------	$204,000	-----	------
1	$44,797	$159,203	$49,032	$93,830
2	$44,797	$114,405	$36,937	$81,734
3	$44,797	$69,608	$24,842	$69,639
4	$44,797	$24,811	$12,747	$57,544
5	$44,797	$0	$3,349	$48,147

EQUIPMENT OWNING COSTS (HOURLY)

END OF YEAR	WORKING HOURS	DEPRECIATION COSTS	INVESTMENT COSTS	TOTAL COSTS
1	2000	$22.40	$24.52	$46.91
2	2000	$22.40	$18.47	$40.87
3	2000	$22.40	$12.42	$34.82
4	2000	$22.40	$6.37	$28.77
5	2000	$22.40	$1.67	$24.07

IN ORDER TO GO BACK TO MAJOR MENU PRESS [Alt]
AND [M] KEYS SIMULTANIOUSLY.

Figure 3-42: Equipment Owning Costs Calculations (Continued)

EQUIPMENT OPERATING COSTS CALCULATIONS

1- Fuel Consumption Costs :

- Equipment Brake Horsepower (HP) = 330
- Full load fuel consumption (gal/hr) = 19.8
  (0.06* BHP)
- Selected Equipment Load Factor (ELF) = 0.6
- Fuel consumption based on ELF (gal/hr) = 11.88
  (ELF* full load fuel consumption)
- Cost of Fuel / gallon ($/gal) = $1.20
- Annual rate of increase in cost of fuel = 10.00%
- Hourly Fuel Consumption = Fuel Consumption * Cost of Fuel/gal.

FUEL CONSUMPTION COSTS

END OF YEAR	COST OF FUEL/GAL.	HOURLY FUEL CONSUMPTION COSTS
1	$1.20	$14.26
2	$1.32	$15.68
3	$1.44	$17.11
4	$1.56	$18.53
5	$1.68	$19.96

2- Service Costs :

- Selected Service Factor = 0.33

- Hourly Service Costs = Service Factor * Hourly fuel consumption costs

SERVICE COSTS

END OF YEAR	HOURLY SERVICE COSTS
1	$4.70
2	$5.17
3	$5.65
4	$6.12
5	$6.59

Figure 3-43: Equipment Operating Costs Calculations

3- Major Repairs Costs :

- Selected Repairs Factor = 0.9
- Total Repairs Costs = $183,600
  (Repairs Factor * [Eqpt cost-Tire cost])

- Repairs Costs (year i) = (i / S) * Total Repairs Costs

S = 1+2+3+4+5 = 15

MAJOR REPAIRS COSTS

END OF YEAR	WORKING HOURS	YEARLY REP. COSTS	HOURLY REPAIRS COSTS
1	2000	$12,240.00	$6.12
2	2000	$24,480.00	$12.24
3	2000	$36,720.00	$18.36
4	2000	$48,960.00	$24.48
5	2000	$61,200.00	$30.60

4- Tire Replacement Costs :

- Selected Tire Life (Hours) = 3000

- Hourly Cost of Tire Replacement ($/Hr.) = $7
  (Tire cost / Tire life)

5- Tire Repairs Costs :

- Tire repairs costs are selected % of tire replacement costs

- Selected % = 15.00%

- Hourly Costs of Tire Repairs ($/Hr.) = $1

Figure 3-43: Equipment Operating Costs Calculations (Continued)

EQUIPMENT OPERATING COSTS (YEARLY)

END OF YEAR	FUEL COSTS	SERVICE COSTS	REPAIRS COSTS	TIRE COSTS REPL.	REP.	TOTAL COST
1	$28,512	$9,409	$12,240	$13,333	$2,000	$65,494
2	$31,363	$10,350	$24,480	$13,333	$2,000	$81,526
3	$34,214	$11,291	$36,720	$13,333	$2,000	$97,558
4	$37,066	$12,232	$48,960	$13,333	$2,000	$113,591
5	$39,917	$13,173	$61,200	$13,333	$2,000	$129,623

EQUIPMENT OPERATING COSTS (HOURLY)

END OF YEAR	WORKING HOURS	FUEL COSTS	SERVICE COSTS	REPAIRS COSTS	TIRE COSTS REPL.	REP.	TOTAL COST
1	2000	$14	$5	$6	$7	$1	$32.75
2	2000	$16	$5	$12	$7	$1	$40.76
3	2000	$17	$6	$18	$7	$1	$48.78
4	2000	$19	$6	$24	$7	$1	$56.80
5	2000	$20	$7	$31	$7	$1	$64.81

Figure 3-43: Equipment Operating Costs Calculations (Continued)

EQUIPMENT OWNING AND OPERATING COSTS SUMMARY

EQUIPMENT CHARACTERISTICS

1- Equipment Description	:		
2- Equipment Total Cost	:	$224,000	
3- Equipment Useful Life	:	5 Years	
4- Equipment Salvage Value	:	$30,000	
5- Cost of new set of Tires	:	$20,000	
6- Method of Depreciation	:	Straight Line	
7- Fuel Consumption Assumptions	:	a) Load Factor =	0.6
		b) Brake HP =	330
		c) Fuel Consump. =	11.88 Gal./Hr.
8- Service Costs Assumptions	:	a) Service Factor=	0.33
9- Repairs Cost Assumptions	:	a) Repairs Factor=	0.9
		b) Total Repairs Cost =	$183,600
10- Expected Tire Life	:	3000 Hours	
11- Cost of Tire Repairs assumed as:		15.00% of Tire Replacement Cost	

EQUIPMENT OWNING COSTS

YEAR	WORKING HOURS (PER YR.)	DEPRECIATION COSTS YEARLY	DEPRECIATION COSTS HOURLY	BOOK VALUE	AVERAGE BOOK VALUE	INVESTMENT RATE	INVESTMENT COSTS YEARLY	INVESTMENT COSTS HOURLY
1	2000	$44,797	$22.40	$159,203	$181,601	27.00%	$49,032	$24.52
2	2000	$44,797	$22.40	$114,405	$136,804	27.00%	$36,937	$18.47
3	2000	$44,797	$22.40	$69,608	$92,007	27.00%	$24,842	$12.42
4	2000	$44,797	$22.40	$24,811	$47,209	27.00%	$12,747	$6.37
5	2000	$44,797	$22.40	$0	$12,405	27.00%	$3,349	$1.67

Figure 3-44: Equipment Costs Summary

EQUIPMENT OPERATING COSTS

YEAR	FUEL COST PER GALLON	FUEL CONS. COSTS		SERVICE COSTS		REPAIRS COSTS		TIRE REPL.COSTS		TIRE REPAIRS COSTS	
		YEARLY	HOURLY	YEARLY	HOURLY	YEARLY	HOURLY	YEARLY	HOURLY	YEARLY	HOURLY
1	$1.20	$28,512	$14.26	$9,409	$4.70	$12,240	$6.12	$13,333	$6.67	$2,000	$1.00
2	$1.32	$31,363	$15.68	$10,350	$5.17	$24,480	$12.24	$13,333	$6.67	$2,000	$1.00
3	$1.44	$34,214	$17.11	$11,291	$5.65	$36,720	$18.36	$13,333	$6.67	$2,000	$1.00
4	$1.56	$37,066	$18.53	$12,232	$6.12	$48,960	$24.48	$13,333	$6.67	$2,000	$1.00
5	$1.68	$39,917	$19.96	$13,173	$6.59	$61,200	$30.60	$13,333	$6.67	$2,000	$1.00

CHARGES OF THE EQUIPMENT OPERATOR

YEAR	YEARLY	HOURLY
1	$32,000	$16.00
2	$38,400	$19.20
3	$41,600	$20.80
4	$44,800	$22.40
5	$48,000	$24.00

SUMMARY OF EQUIPMENT COSTS

YEAR	TOTAL OWNING COSTS		TOTAL OPERATING COST		OPERATOR COSTS		TOTAL EQUIPMENT COSTS	
	YEARLY	HOURLY	YEARLY	HOURLY	YEARLY	HOURLY	YEARLY	HOURLY
1	$93,830	$46.91	$65,494	$32.75	$32,000	$16.00	$191,324	$95.66
2	$81,734	$40.87	$81,526	$40.76	$38,400	$19.20	$201,661	$100.83
3	$69,639	$34.82	$97,558	$48.78	$41,600	$20.80	$208,798	$104.40
4	$57,544	$28.77	$113,591	$56.80	$44,800	$22.40	$215,934	$107.97
5	$48,147	$24.07	$129,623	$64.81	$48,000	$24.00	$225,769	$112.88

Figure 3-44: Equipment Costs Summary (Continued)

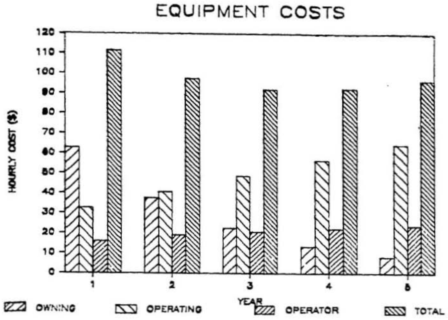

Figure 3-45: Graphical Representation of Equipment Costs

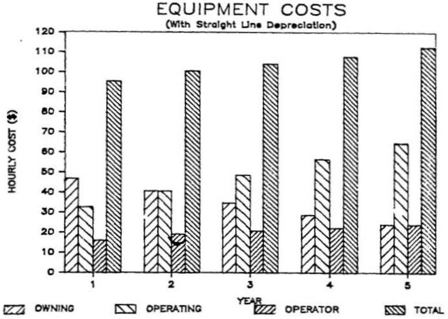

Figure 3-46: Sensitivity Analysis Effects on Equipment Costs

3.12. ADMINISTRATION

Project administration deals with the general administrative, financial and personnel aspects of a construction project. Financial and personnel aspects are basically accounting functions, which include; payroll, accounts payable-subcontractor, accounts payable-material, accounts receivable, and general ledger & job costs. A typical information flow diagram of an accounting system is shown in Figure 3-47.

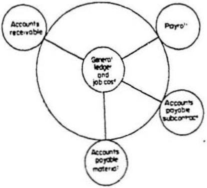

Figure 3-47: Flow Diagram Accounting System

The general ledger and job cost system interacts with all other subsystems to form the basis for estimating and cost control.

Tasks related to construction administration have obvious integrated package applications. An integrated package module representing the accounting functions has been developed on Lotus 1-2-3 and is described in the following section.

3.12.1. Computer Module

Accounting functions consists of payroll, account payable-subcontractors, account payable- material, account receivable, and general ledger and job costs. To develop a complete accounting system on Lotus 1-2-3, each subsystem has to be developed independently and then linked together. The subsystems are discussed as follows.

Payroll: Construction contractors quite often select their payroll operation as the first accounting function to be performed by a computer. Performing payroll calculations by computer is time saving and cost effective because calculating taxes and other deductions is highly repetitions. Generally the payroll sheet consists of information about the job-site name, employee name, social security number, general trade classification, time worked, gross earnings, and deductions. One such payroll sheet is developed on Lotus 1-2-3 and is shown in Figure 3-48.

Accounts Payable-Subcontract: Accounts payable is important to contractors because a common problem in the construction industry is controlling cash flow and tracking money the firm owes to suppliers and sub contractors. The accounts payable module processes major sub contractors and material orders that are disbursed in a series of payments with the retention part of the agreement. On every job the sub contractor renders his bills at the end of the job and the cost is accounted for in that period. Disbursements to sub contractors are approved by the project manager and forwarded to computer processing. Billings, payments, and retentions for the current period are then calculated by the computer. A typical accounts payable-subcontract sheet, developed on Lotus 1-2-3 is shown in Figure 3-49.

Accounts Payable-Material: This system processes all job-related invoices that are not entered into the accounts payable-subcontract system. Generally, invoices are approved for payment by the office manager at each project site. The major part of this system is an accounts payable journal, which serves as an audit-trial of all invoices entering the system. A typical account payable journal is shown in Figure 3-50.

Accounts Receivable: This is the least popular program of accounting modules. It is rarely used by either small and large construction firms. Basically, the receivable program is similar to accounts payable with the difference that customers are listed instead of suppliers and subcontractors and checks are replaced by invoices to be sent to customers. A list of unbilled items are sometimes included among additional reports not available with accounts payable.

General Ledger and Job Cost: The general ledger module serves as the central part of the accounting system. Job costs, accounts payable, accounts receivable, and payroll modules are, in effect, sub-ledgers, and the final figures from these sub-ledgers are posted to the general ledger module. A typical general ledger sheet is shown in Figure 3-51. Various types of reports and financial statements are then produced from the general ledger module.

Lotus 1-2-3 solutions to accounting problems will probably not become

JOB NO	4	WEEKLY PAY-ROLL	SHEET NO	1
NAME OF WORK ABC		LOCATION XYZ	WEEK Feb. 15, 1985	

OCCUP.	NAME	EMPL'S NO	TIME WORKED M T W T F S S	TOTAL HOURS	RATE	GROSS EARNINGS REG. EARN.	EXCESS EARN.	TOTAL EARN.	DEDUCTIONS INCOM TAX	OTHR.	TOTAL DEDUC	NET PAID AMOUNT	CHECK NO
Laborer	Wm. Jones	104	8 8 8 8 8	40	$5	200		200	20		20	$180.0	561
Laborer	Ken Brown	106	8 8 8 8 8	40	$5	200		200	20		20	$180.0	562
Carpenter	Wm Fowler	112	8 8 8 8 4	36	$7	252		252	25.2		25.2	$226.8	563
Carpenter	Allen Abbott	113	8 8 8 8 4	36	$7	252		252	25.2		25.2	$226.8	564
Carpenter	Edgar Sparkes	114	8 8 8 8 8	40	$7	280		280	28		28	$252.0	565

TOTAL $1,184

Figure 3-48: Payroll Sheet

ACCOUNTS PAYABLE-SUBCONTRACTORS DATED 2/28/1985 SHEET NO 1

SUPP	NC	NAME	INV. NO	ORDER	JOB	REFERENCE	POSTED	PAYABLE	PAID	RETENTION
ACM	4	ACME WIRE-IRON WORKS	37565	504516	931	0		$38.8	$0.0	$0.0
ALU	1	ALUMINUM-ARCHET.	8690	505885	826	2685		$2,685.5	$0.0	$0.0
ALU	4	XYZ COMPANY	2154	506987	260	9334		$8,400.6		$933.4
ARM	3	J. LANDSCAPING	77509	507931	775	0		$620.0		$620.0
							TOTAL	$11,744.9		$1,553.4

Figure 3-49: Accounts Payable-Subcontractors

ACCOUNTS PAYABLE-MATERIAL				DATED 2/28/1985				SHEET NO 1	
SUPP	NO	SUPPLIER	INV.NO	DATE INV.	DATE DUE	INVOICE AMOUNT	TAX CODE	TAX AMOUNT	ACCOUNT PAYABLE
BET	1	ABC STEEL CO.	142473	3/3/85	03/25/85	$2,875			$2,875
BET	1	ALFA STEEL CO	145301	3/13/85	3/25/85	$584	1	$68	$452
BET	1	ALFA STEEL CO	145302	3/16/85	3/28/P5	$3,065			$3,065
								TOTAL	$6,592

Figure 3-50: Accounts Payable-Material

GENERAL LEDGER							SHEET NO 1 DATE 2/28/1985	
DESCRIPTION	REF	DATE	CODE	LABOR	MATERIAL	SUBCONTR.	BILLING	RETENTION
Acc.Pay.Mat	911	3/25/85			$6,592			
Acc.Pay.Sub	912	2/28/85				$11,745		$11,553
Acc.Rec	913	2/28/85						
Payroll	914	2/15/85		$1,184				
**** TOTAL BALANCE TO DATE ****				$1,184	$6,592	$11,745	$0	$11,553

Figure 3-51: General Ledger Sheet

commonplace because there are other custom software packages for microcomputers that handle construction accounting very well. This fact was also substantiated by the contractors who participated in the 1985 computer utilization survey. Almost all contractors using the commercially available accounting software were quite satisfied with the performance of these packages.

However, most of the currently available accounting software packages are based on USA accounting procedures. Care should therefore be taken while selecting accounting packages for use in Canada.

3.13. SUMMARY

The applications illustrated in this chapter reveal the usefulness of integrated packages in the construction industry. Each application applies to a different task, and this variety shows the diversified use of integrated packages in the construction industry. After examining the integrated package systems and reviewing their applications, it is believed that integrated packages need no one to recommend them. With the program format, the ease in writing programs, the ability to maintain data files, and the ability to transfer data into other programs, integrated packages recommend themselves. All of these features lead to many uses for integrated packages in the construction industry. Even though integrated packages may have some shortcomings because of their simplicity, there isn't an area in construction operations that could not find a use for integrated packages.

Chapter 4

CRITERIA FOR THE SELECTION OF COMPUTER SYSTEM

Criteria for the selection of a computer system for construction contractors with little or no experience in electronic data processing are outlined in this chapter. The criteria are designed with a view to alleviating the difficulties faced by construction contractors [8] in the selection of a computer system. This analysis will focus on the fundamental understanding of computer terminology and hardware/software selection procedures. Pre-implementation procedures and specific recommendations for computerization are also outlined.

4.1. FUNDAMENTAL UNDERSTANDING OF COMPUTER SYSTEM

The computers used by construction contractors can be classified [2] in three broad categories: microcomputer, minicomputer, and mainframe. A microcomputer is a small desk top machine such as an IBM PC or Apple microcomputer which can be purchased for as little as $2,500. Mainframe computers are large computers with multi-user capability and other features. The IBM 370 family of computers, the 303X, 3008X series computers, are some examples of mainframe computers. A minicomputer is a machine which comes in between micro and mainframe, Examples of minicomputers are Digital Equipment Corporations, VAX family of computers (i.e PDP 11/780). The cost of minicomputers ranges between $20,000 to $80,000. All three types of computers differ in their capacities, speeds, and prices. In this study, only microcomputers are discussed because of their increasing popularity in the construction industry.

In general, computer systems are comprised of two interrelating subsystems: hardware and software.

4.1.1. Hardware

Hardware is the physical subsystem of a computer. It consists of the following components: 1) central processing unit [CPU], 2) input and output devices, and 3) secondary storage devices. A typical computer processing system is illustrated in Figure 4.1.

The central processing unit is the heart of the computer. It performs the functions of control, storage, arithmetic and logic for the entire system. The control unit supervises and schedules the activities of the entire computer system; it receives orders one by one sequentially, interprets them, and directs the operations accordingly [37]. A typical small computer will execute a single instruction in one to ten millionth of a second. In order to perform this task at such a high speed, the instructions, or data, must be stored in fast access storage referred to as main mamory. Primary memory capacity is measured by "K-bytes", where "K" represents 1,024 bytes and a byte represents one character, letter, or number and usually consists of eight bits. A bit can have a value of zero

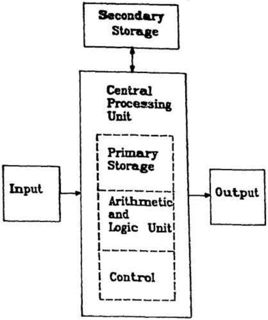

Figure 4-1: Computer Processing System

or one. The primary storage unit is divided into small sections called "locations" each of which has a capacity of one byte and its own label, called an address, which instructs the CPU to access a location. The most important section of the CPU is the Arithmetic/Logic Unit (ALU) which performs arithmetical operations (add, subtract, multiply, and divide) and logical operations (comparing numbers or symbols) on one pair of numbers at a time [37].

Input and output devices are similar to typewriters with added circuitry. The user inserts information, or data, into the computer from a keyboard and the computer prints or displays the information entered or requested. Input devices may be CRTs, card readers, magnetic tapes, disk drives etc. whereas the output devices may be the printer, CRT, punched cards, magnetic tapes etc. The computer displays letters, numbers and characters inserted by the operator on the monitor, which is usually known as CRT. The CRT's output is called "soft copy" because no permanent record is made available. The copy printed on paper is called the "hard copy" because it can be filed as a permanent record. Printers are peripheral devices which produce the hard copy. Printers require paper sheets and can be used as input and output device. Printing speed ranges from 40 to 180 cps (characters per second). Another type of input peripheral is the card reader which is used only for large mainframe computers.

Because limited capacity makes it impossible to keep all company records in the main storage unit, some type of secondary storage device is also required. Using this device, which may be a magnetic tape or a disk, is more economical than increasing the main memory for the capability of storing amounts of data. Two types of magnetic disks are available . One is a floppy disk, or diskette, which is small with a flexible plastic base. It resembles an ordinary recording disk wrapped in square, hard paper. It cannot be removed from the paper but it rotates freely within the cover. The second type of disk is a hard disk, larger than the floppy disk, uncovered, and with a rigid metal base.

Microcomputers have been on the market since 1975. They consist of a single central processing unit (CPU), a CRT terminal, one or two printers, and one or more disk drives. The microcomputer is generally a single user system. In other words, when a person is creating data or executing a program on the system, he or she has exclusive use of the system. Some microcomputer operating systems do allow multi-tasking such as printing a report while the user is working on updating a file or running a different program. Since microcomputers usually do not have an abundance of memory or CPU speed to support concurrent operations, multi-tasking may significantly slow the response to the user. One of the areas that is most rapidly changing in microcomputers is communications. The most significant of these developments is in local area networks (LAN). This allows multiple microcomputers to be tied together by high speed data links (i.e., 50 megabits/second or six million characters per second) [18]. LAN operations allow the sharing of resources (printers, hard disks, etc.) between micros and provide the ability to transfer data files. Currently most LAN software are available from third party vendors and not directly from major microcomputer manufacturers [18]. As major manufacturers settle on particular standards and begin supporting LAN then a new stage of microcomputer applications will develope.

Microcomputers do not require any particular physical environment except that temperatures above 100 F^{o}, excessive humidity, dust or cigarette smoke can adversly affect the system, especially when it is in use. Microcomputers have relatively slow execution time because the word length (the amount of data that a computer can handle at one time) in most of them is no more than 16 bits. This deficiency in execution speed is decreasing because CPU speeds are increasing rapidly as micro generations evolve through 8-16-32-64 bit machines. Hewlett-Packard already markets a 32-bit machines, while a 64-bit machine is planned in Japan [26].

4.1.2. Software

Software, or programs, are a sequential set of instructions that command the computer to perform a particular task. Software are commonly divided into two types: system software and application software.

SYSTEM SOFTWARE: System software is collectively the administrative programs of the computer system. Each program has its special control responsibility. The most important system programs are:

1. Operating System: The operating system has overall control of operations. It puts the program to be executed in a sequential order, and monitors the entire computer operation. Generally, operating systems are sold and serviced by application software manufacturers. System software maintenance is rarely required because these programs have been on the market for a sufficient period of time to have been well-tested and debugged. Because application software are often written and designed for only one kind of operating software, the computer user should be familiar with the operating system of his/her own computer.

CP/M is the most common operating software. There are more construction and business applications for a computer with a Z-80 microprocessor and a CP/M system than for any other. CP/M was written by Microcomputer Applications Associations (MAA) in 1974, and is a single user software program. The simplicity and reliability of the file system is an important key to the success of CP/M.

The major difference in operating system is the way programs are scheduled for execution. There are four different categories of operating software: batch, real-time, time-sharing, and multi-processing.

A system with a batch processing operating system handles programs one at a time. No other program is read in until the previous one is completely off line. The CPU is idle untill input or output is completed; thus a great deal of delay occurs during program processing.

With real-time processing, when the CPU is not utilized by process operation, batch processing may be performed. Real-time processing is not very useful for business applications and is mostly used for manufacturing products, telecommunications, military command and control systems.

Time-sharing is a process whereby the computer processes programs at such a rapid rate that the impression is created of multi-users sharing the CPU. This is not in actuality the case. Delays occur during I/O transfer and during this delay time another program is brought in to be executed. It may take the CPU one-millionth of a second to execute an instruction, but one-thousandth of a second to send a piece of data out to a peripheral. This system includes a feature which keeps programs separate from one another.

The multi-processing system has multiple processors, or CPU's. These CPU's share one main storage. This approach is benefical in that when one microprocessor malfunctions, another serves as backup. Computers with multiprocessors are not yet common, but with microcomputer CPU chips becoming some of the least expensive parts of computer systems, it will not be long before hardware manufacturers begin to utilize multiprocessors with computers.

The most common operating system for microcomputers are the batch processing operating system because only one user can access the system and it will be unnecessary to install multi-user system software. However, time-sharing is common for minicomputer systems.

2. Assemblers, Compilers, and Interpretors: Because it is difficult for an average computer programmer to write a program in the machine language format understood by the computer, computer instructions are entered by the user by means of a higher level computer language (FORTRAN, BASIC, PASCAL, etc). These languages, however, are not readily comprehended by the computer until they are translated into machine language. Assembler, compiler, and interpretor programs translate higher level programming languages into machine language.

3. Peripheral Control: As its name implies, the peripheral control program monitors communications among all peripherals and insures the correct flow of data to output peripherals.

4. Debuggers: In case of an error in an application program, debuggers help the programmer find the error by displaying messages. When a bug (error) occurs, the program is executed step by step; debuggers can then relate the error

occurred to one of many possible errors contained in the debugger listing. The example of a debugger program is "Norton Utility"

APPLICATION SOFTWARE: Application software performs the actual work task. It is perhaps the most important item in the overall computer system for the users. Contractors require software designed and tailored specifically for their particular type of job. The application software most commonly used by typical small construction firms are the computer programs that perform the basic accounting functions like general ledger, payroll, and accounts payable/receivable. These program modules may be structured in one of two ways. First, they may operate only on one specific set of data in which case they are referred to as "stand-alone" because for each program a separate set of data is required. Or, the modules may share data, in which case they are termed "integrated". Integrated systems are highly desirable because they eliminate the necessity of inserting the same data for different programs, or manipulating the output of one program to serve as input for another.

4.2. HARDWARE SELECTION

Hardware characteristics and current purchase prices for commonly used small business microcomputer systems are shown in Table 4.1. These business systems are appropriate for construction contractors when the software associated with the system is compatible with the contractor's data processing requirements. Therefore, before hardware selection is discussed further, the first and most essential element in successfully implementing a computer system should be mentioned: FIND THE RIGHT APPLICATION SOFTWARE FIRST, THEN

MANUFACTURER	SYSTEM	PRICE $	MEMORY (RAM) (k-byte)		MASS STORAGE CAPACITY				EXPANSION SLOTS
					Floppy Disk k-byte		Hard Disk m-byte		
			Std.	Max.	Std.	Max.	Std.	Max.	
IBM	IBM PC	$3,800	64 k	256 k	360	360	-	-	
IBM	IBM PC XT	$4,200	256 k	640 k	720	10,360	10	10	8 standard
COMPAQ	Portable	$4,399	128 k	640 k	360	720	None	None	3
COMPAQ	Deskpro 296	$6,950	128 k	640 k	360		10		6
RADIO SHACK	TRS-80 Model 4	$3,100	64 k		360	360	None	None	
KAYPRO	Kaypro 2	$3,500	64 k		200 k	200 k	-	-	3
APPLE	APPLE MACINTOSH	$3,500	64 k	512 k	400 k	400 k			5
TANDY RADIO SHACK	Tandy 1000	$3,000	128 k	640 k	360 k				3

Table 4-1: Microcomputers Commonly Used for Small Business Applications

LOOK FOR THE HARDWARE [22]. Selecting software will be discussed in the next section.

The reputation of the vendor is an important factor in the hardware selection, because once the hardware is installed, the user will be forced to depend on the vendor to service the system. In evaluating vendors, their service record with other companies should be investigated.

The geographical proximity of the vendor to the construction firm is another important consideration. For fast service, the service centre should be as close as possible. If the vendor does not have an in-house service department, the length of time necessary for minor service and the fee, as well as who pays the fee for shipments, should be investigated.

Moreover, the terms of the hardware warranty should be clearly understood, i.e., what is actually covered, for how long, etc. If no problem arises within the first full month of use, it is unlikely that there will be a major system failure within the next two or three years. However, mechanical maintenance or service will be required.

The primary consideration in selecting hardware is determining system type and size. Making a decision about whether to use a micro-based, mini-based or mainframe based system is very difficult because of the variety of systems available and the multitude of companies supplying them. Based on the computer utilization survey results, discussed in chapter 1, the following situations were observed where systems have been successfully used. Contractors with an annual contract volume up to $12 million have chosen microcomputers for their data processing needs whereas contractors with an annual contract volume in excess of $12 million have preferred minicomputers.

Another important aspect to be considered in selecting hardware is the type and size of storage devices as well as the type and number of input and output peripherals. A reputable vendor will be able to size the storage devices accurately and make recommendations for future expension. Inexpensive dot matrix printers with printing speeds of 120 to 180 characters per second should be adequate for most report generation applications. A letter quality daisy-wheel printer that prints at a much slower rate is recommended for word-processing applications.

4.3. SOFTWARE SELECTION

Software is the most important element of the small computer system. In most cases, problems with computer systems are caused by software limitations or errors, not hardware failure. The results of the computer utilization survey [8] indicated that there were far more variations in software quality and support than in hardware reliability and service. Therefore, the selection of software is critical to the overall process of computerization.

The most intelligent way to evaluate application software is to experiment with it on a trial bases. This can often be accomplished by means of an extended visit with the software vendor. Before the demonstration, sample data should be assembled and used as input for the demonstration to verify the capability and flexibility of the software modules. It is also important to consult with other contractors who have purchased software similar to that which is being considered. Once the decision has been made to buy a mini-system or a micro-system, a decision in large part determined by the contractor's budget, a careful study should be made of the firm's software needs. For example, the usual accounting or bookkeeping system used by contractors includes payroll, job cost, accounts payable/receivable, and general ledger modules. While selecting accounting modules, only integrated systems should be given serious consideration.

Criteria for evaluating software include ease of inserting data and creating files, time involved in output, typ. and number of reports generated, documentation, training, and support [2]. Each one of these criterion is discussed below.

The menu-driven features of pre-written application software simplifies data entry. Through this technique, th.. user is prompted for responses and given options for input/output and subprogram selection. The problem with menu-driven operations is the difficulty of re-entering in case of an error. In evaluating software, it is useful to determine how much data must be re-entered and how simple it is to track processing errors.

The capability of producing a large number of reports should also be considered while ·valuating the software. In general, the more reports that the software can provide, the better the system is.

Every application software program should be accompanied by user documentation. Some portions of the documentation are built into the system and may be displayed on the screen if help is needed. Only portions of the documentation can be built into the program because of economy and hardware capability. Therefore, a user manual is required for complete instructions. The user must be able to locate specific information quickly in the user manual and readily comprehend the examples presented. Otherwise the manual will not be utilized and much of the system's capability will not be realized.

The availability of training and support are also very important considerations. A substantial portion of the software purchase price is allocated to training and support. Generally, the cost of training the contractor's representative at the software company, home or regional office is included in the price of the package. Some vendors offer training sessions to prospective buyers also. Most of the software companies also offer on site training. Most of the contractors think, however, that on site training is well worth the cost.

Finally, a software vendor must be evaluated for its support service. No matter how good the training is, or how useful the manual, there is always the possibility of problems arising after training that cannot be resolved without professional help. Generally, software vendors provide support services up to one year after the purchase of the software. Some software campanies have a toll free number, but usually limit the time and/or number of calls. An evaluation of vendor service is as important as the evaluation of documentation, training and support.

4.4. PRE-IMPLEMENTATION PROCEDURES FOR COMPUTERIZATION

After the decision is made to computerize, goals and objectives for the system to be implemented must be established as an initial step. The remaining steps of the implementation process will be governed by these goals. A successful computer system implementation will provide tangible long-term benefits; therefore long-term goals should be established based on current needs and future business expectations.

Computers do not perform miracles. If managerial problems exist within the company, computers will make them worse [22]. People who work with computers must feel comfortable with them. Therefore, before implementing the computer system, a brainstorming session is recommended. During this brainstorming, contractors must be creative. Everyone in the office should contribute their ideas, and consideration should be given to all ideas, whether they seem bad or good.

After selecting the system an approximate cost estimate of the system must be made. The initial cost of hardware and software will obviously be included. Training cost may also be applicable as well as the time spent for personnel to be trained. Monthly costs such as interest, phone lines, maintenance, and accessories should be added to the total cost.

When all studies have been completed and it is decided that automating files is benefical, careful plans should be made about when and how the system will be installed. Nothing is more disheartening than to have a computer delivered, then have it sit around inoperable for three to four months. Once the hardware and software are ordered, delivery dates should be set up and coordinated with the vendor.

An operator and a backup operator should be selected. Those chosen must take advantage of the training sessions offered by the software vendor. Even if on-site training for one or two days is planned in the future, these classes will still be beneficial.

Preprinted forms are needed to simplify procedures for entering initial data into the system. Software vendors can supply contractors with samples of these forms.

The place where the computer is to be located should be prepared before the computer arrives. Most small computers today do not require special conditions. Microcomputers are adaptable to most ordinary climatic conditions.

Preparation of all data files before the system's arrival will facilitate the use of the system's full capacity. If it is impossible to prepare all data files, then at least a portion of them should be ready, especially when on-site training is scheduled.

4.5. SPECIFIC RECOMMENDATIONS FOR COMPUTERIZATION

Usually, the contractors making their first computer purchase will not have the time or in-house expertise to write their own computer programs. Non compatibility of commercially available application software with in-house procedures will also limit the direct use of these software packages for contractors. Moreover, some commercially available application software costs more than the hardware. So, the best decision for a small contractor is to adapt general application software such as electronic spreadsheets or integrated packages. These integrated packages, such as Lotus 1-2-3, allow the users who are unfamiliar with programming languages to write their own routines for estimating, scheduling, equipment cost/depreciation and other construction management functions, without disturbing their in-house procedures. Uses of an integrated package in modelling construction management systems have been detailed in the previous chapter. Computerizing the organization's data processing needs with the integrated packages on a microcomputer is the cheapest option available for small contractors. A complete computer system which includes microcomputer, dot matrix printer, and an integrated package (such as Lotus 1-2-3) can presently (1985) be purchased at a price as low as $3,500.

Despite the cheaper cost and easy use of integrated packages, contractors may want to use the commercially available software packages for some of their data processing needs. In such case, the contractors should check the compatibility of commercially available software with their data processing needs.

It is difficult to recommend a specific hardware manufacturer or software vendor without knowing the contractors' unique data processing requirements. Descriptions of the popular commercially available software for performing construction management functions are therefore documented in the Table 4-2 and Table 4-3.

Table 4-2 documents thirteen project planning and control software. Five of these software were tested on the IBM personal computer at Memorial University of Newfoundland, Canada. Information on the remaining software in Table 4-2 was obtained by evaluating the software manufacturers catalogues, software surveys, and relevant literature [2]. In evaluating the software emphasis was given to extracting their specific features and compatible hardware. The following features have been studied; 1) network type, 2) capability of handling number of activities and number of projects, 3) options for user definable reports, 4) capability to interface with other programs, 5) provision for resource allocation, and 6) documentation.

Table 4-3 illustrates the evaluation of software for estimating. The information on most of the software indicated in this table is taken from a survey [32] that was conducted in October 1984 in the USA to determine different options available on the market for computerizing the cost estimating system. Additional information in Table 4.3 was obtained through the manufacturers' vendor catalogues and demonstrations by hardware/software vendors. As the cost estimating process is commonly divided into three major steps; the quantity survey, the pricing study, and the presentation of the results, the capabilities of the software to perform each of these steps were evaluated and accordingly included in the Table 4.3.

SOFTWARE NAME	COMPANY NAME & ADDRESS	PRICE	COMPATIBLE HARDWARE	FEATURES
Harvard Project Manager	Harvard Software, Inc. 521 Great Road Littleton, MA 01460	$395	IBM PC and Compatibles Requires 128K RAM with two disk drives	-200 activities per project with unlimited subprojects. -only PERT networks -Network graphics reports available on dot matrix prints. -Does not deal as thoroughly with the planning of resources and their related costs. Only activity. -Program allows up to four "windows" to be displayed on the screen at one time, e.g., while looking at the "PERT" chart, the bottom window may contain the "node description". -Excellent tutorial. -DIF formats can be created for interfacing with other software.
ManageMint	Institute for Scientific Analysis, Inc. 36E Baltimore Pike Suite 106, Media PA 19063	$895	IBM PC, TRS-80 Requires 128k RAM with two disk drives	-999 activities per project. -CPM and PERT networks -Performs Monte Carlo Simulation. -Provision for user definable reports. -Does not provide resource allocation. -Excellent user manual.
MicroGANTT	Earth Data Coopertion P.O. Box 13168 Richmond, VA 23225	$395	-Compatible with any MSDOS, CPM-80 operating systems.. -Requires 128k RAM one disk drive.	-Precedence networks only. -Unlimited activities. -Does not provide user definable reports. -No provision for resource allocation. -Stores its Gantt chart in BASIC format. These files may be used with any program with a BASIC interface. For instance, cost information may be read into Lotus 1-2-3 for further analysis.

Table 4-2: Project Planning and Control Software

SOFTWARE NAME	COMPANY NAME AND ADDRESS	PRICE	COMPATIBLE HARDWARE	FEATURES
MicroTrak	Softrack Systems P.O. Box 22156 AMF Salt Lake City, UT 84122	$595	-IBM PC and other hardware with MSDOS or CP/M operating systems. -Requires 128k RAM and one disk drive	-Precedence networks only. -5,000 activities. -Does not provide resource allocation. -User definable reports module is optional. -Can be interfaced with dBASE. -Poor documentation.
Milestone	Digital Marketing Corp. 2363 Boulevard Circle Walnut Creek, CA 94595	$295	-Can run on machines with operating systems: CP/M, CP/M-80, UCSD Pascal. -Requires 128k RAM & one disk drive.	-Both IJ and Precedence networks. -3,500 activities -Does not provide resource allocation. -Provide only one user definable report. -Provides a gantt chart.
NETCON	Project Planning, Management & Control Systems 1309 East 132nd Street Burnsville, MN 55337	$595	IBM PC	-Provide IJ networks. -Precedence network module is optional and costs additional $595. -1000 activities. -Does not provide resource allocation. -Provides a gantt chart and networks both. -Excellent documentation.
Pertmaster	Westminster Software Inc. 3000 Sand Hill Road Building 4, Suite 245 Menlo Park, CA 94025	$695/ $895	-IBM PC-XT, Company, GRID Compass, Sirius/ Victoo, and Eagle PC. -Requires minimum of 50k with one disk drive.	-IJ and Precedence -1500/2500 activities -No provision for resource allocation. -Provides user definable reports. -Plots a Gantt chart. -New version will support plotters and contain an integrated data base to facilitate manipulation of task-related financial · .formation.

Table 4-2: Project Planning and Control Software (Continued)

SOFTWARE NAME	COMPANY NAME AND ADDRESS	PRICE	COMPATIBLE HARDWARE	FEATURES
Plan/Trax	Omicron Software 57 Executive Park South N.E. Suite 590 Atlanta, GA 30329	$595	IBM PC	-IJ networks only. -700 activities -No provision for resource allocation. -Does not provide user definable reports. -Color/Graphics Support.
PMS-II/RMS-II	North American MICA Inc. 11772 Sorrento Valley Road Suite 100 San Diego, CA 92121	PMS-II =$1295 RMS-II =$995	Compatible Operating Systems: PCDOS, MSDOS, CPIM, CP/M-86	-IJ networks only -2750 activities with unlimited subprojects. -No resource allocation -Does not provide user definable reports. -Does not provide network plotting.
PMS 80	Pinnell Engineering 5331 S.W., Macadam Avenue Suite 270, Portland OR 97201	$995	Operating System: CP/M	-IJ and Precedence networks. -1000 activities -No provision for resource allocation. -Provides user definable reports. -Network plotting (optional).
Primavera Project Planner	Primavera Systems, Inc. 29 Bala Ave., Suite 224 Bala Cynwyd, PA 19004	$2,500	Operating Systems: MSDOS	-IJ and precedence networks. -10,000 activities. -Allow resource allocation and levelling. -Provides user definable reports. -Can be interfaced with plotter for graphics.
Project Control Program	Project Planning Services 371 Main Street Collegeville, PA 19426	$900	IBM PC, DEC Rainbow	-IJ networks. -Unlimited activities -No provision for resource allocation. -Does not allow user definable reports. -Provides plotter graphics.
Project Management	Institute of Industrial Engineers 25 Technology Park	$175	IBM PC, Apple, TRS-80 Requires minimum 64k RAM and one disk drive.	-Precedence networks only -300 activities -Provides resource allocation. -Does not allow user definable reports.

Table 4-2: Project Planning and Control Software (Continued)

PROGRAM	VENDOR	MODE[1] OF OPERATION		DATA BASE SIZE	MAX. NO. OF COST ITEMS THAT CAN BE PROCESSED	AUDIT TRAIL	QUANTITIES TAKE-OFF	ITEMS FOR WHICH DATA BASE CAN BE MODIFIED[2]									NO. OF STANDARD OUTPUT REPORTS	HARDWARE REQUIRED MEMORY	SOFTWARE COSTS
		B	I					A	CD	PT	LR	PL	CM	MP	ER	P			
JOB COST MANAGEMENT SYSTEM	Golden Data Corporation, P.O. Box 8225 Corpus Christi, TX 78412		Y	180K	600 Items/ 7000 price unit	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	7	(Micro-computer) TRS-80, Mod III with 2 drives	$3,000
MC² INTERACTIVE COST ESTIMATING SYSTEM	Management Computer Controls Inc., 2881 Directors Cove, Memphis Tenn 38131		Y	10MB		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	200	(Minicomputer) IBM System 34/36 96K	US$20,000 for minimum package
CONSTRUCTION REPORTING SYSTEM	MSG Association Inc., P.O. Box 37808 Omaha, NE 68137		Y			Y											12	(Micro-computer) TRS-80, Mod 11 12, or 16/ 2 disks 64K	$ 600
COMPLETE CONSTRUCTION MANAGEMENT SYSTEM	Computer Spectrum Inc.,	Y		1/32767	32767/ JOB	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	35	(Minicomputer) Digisonix II, 10 MB Min. Fixed Disk 64K	
CONCORD SYSTEM	Concord Management Systems, Inc.		Y	Un-limited	Unlimited	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	9	(Minicomputer) TI Business System, 300,800 Series	$8,500

1. B=Batch Mode, I=Interactive Mode
2. A=Addition of Cost Items, CD=Company Procedures,
   PT=Project Timing, LR=Labour Rates,
   PL=Project Location, CM=Construction Methods
   MP=Material Prices, ER=Equipment Rates, P=Productivity

Table 4-3: Estimating Software

PROGRAM	VENDOR	MODE[1] OF OPERATION		DATA BASE SIZE	MAX. NO. OF COST ITEMS THAT CAN BE PROCESSED	AUDIT TRAIL	QUANTITIES TAKE-OFF	ITEMS FOR WHICH DATA BASE CAN BE MODIFIED[2]									NO. OF STANDARD OUTPUT REPORTS	HARDWARE REQUIRED MEMORY	SOFTWARE COSTS
		B	I					A	CD	PT	LR	PL	CM	MP	ER	P			
ESTIMATING FOR THE IBM SYSTEM 23/DATAMASTER	Contractor's Data Systems, Inc., P.O. Box 399 Newberry, S.C. 29108	Y		4500	4500	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	5	(Minicomputer) IBM System 23/Datamaster; 64K	$7,000
CONTRACTOR COST ACCOUNTING			Y		30,000	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		(Micro-computer) Radio Shack T. 1-80III, 2 Disk drives; 64K	$5,000
RICHARDSON ESTIMATING SYSTEM	Richardson Engineering Service, Inc., 909 Rancheros Dr. P.O. Box 1055 San Marcos CA 92069		Y	999,999 items	Unlimited	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y		(Minicomputer) WANG 2200 Series with 10 MB; 64K	$22,000
STAR	R.S. Means Co.Inc. 100 Construction Plaza, Kingston, MA 02364		Y	20,000 Lines	Depends on Disk	Y		Y			Y	Y	Y	Y	Y	Y	11	(Micro-computer IBM PC XT TRS-80 II Mod. 16 DEC Rainbow	$ 2,500
APEX	R.S. Means Co.Inc. 100 Construction Plaza, Kingston MA 02364		Y	20,000 lines	Depends on Disk	Y	Y	Y			Y	Y	Y	Y	Y	Y	11	(Micro-computer) IBM PC with hard disk only	$3,000

1. B=Batch Mode, I=Interactive Mode
2. A=Addition of Cost Items, CD=Company Procedures, PT=Project Timing, LR=Labour Rates, PL=Project Location, CM=Construction Methods, MP=Material Prices, ER=Equipment Rates, P=Productivity

Table 4-3: Estimating Software (Continued)

PROGRAM	VENDOR	MODE[1] OF OPERATION		DATA BASE SIZE	MAX. NO. OF COST ITEMS THAT CAN BE PROCESSED	AUDIT TRAIL	QUANTITIES TAKE-OFF	ITEMS FOR WHICH DATA BASE CAN BE MODIFIED[2]									NO. OF STANDARD OUTPUT REPORTS	HARDWARE REQUIRED MEMORY	SOFTWARE COSTS
		B	I					A	CD	PT	LR	PL	CM	MP	ER	P			
CONCRETE ESTIMATING 1G02	Estimation, Inc., 805 L. Bookwood Court, Linthiam Heights MD 21090		Y		3500/ Job	Y	Y	Y			Y		Y	Y	Y		3	(Micro computer) Contractor I 64K	$3,000
MASONARY ESTIMATING 1G04	Estimation, Inc.,		Y		10000/ Job	Y	Y	Y			Y		Y	Y	Y		6	(Micro-computer) Contractor I 64K	$3,000
DRYWALL/ ACOUSTICAL CEILING ESTIMATING 1G01	Estimation, Inc.,		Y		10000/ Job	Y	Y	Y			Y		Y	Y	Y		6	(Micro-computer) Contractor I 64K	$3,000
CARPENTRY ESTIMATING 1G03	Estimation, Inc.,		Y		10000/ Job	Y	Y	Y			Y		Y	Y	Y		6	(Micro-computer) Contractor I 64K	$3,000
COSTMATE	SIS. SUNDATA Two Glenhardie Corporate Center 1285 Drummers Lane Wayne, Penn. 19087		I	10,000 Items	Depends on Disk			Y			Y	Y		Y				(Micro-computer) IBM PC 96K	

1. B=Batch Mode, I=Interactive Mode
2. A=Addition of Cost Items, CD=Company Procedures,
   PT=Project Timing, LF=Labour Rates,
   PL=Project Location, CM=Construction Methods
   MP=Material Prices, ER=Equipment Rates, P=Productivity

Table 4-3: Estimating Software (Continued)

Chapter 5
SUMMARY AND CONCLUSIONS

Computer applications in the construction industry are increasing because of the availability of inexpensive yet extremly powerful microprocessor-based computer systems. Even the smallest construction contractor can now afford to purchase the computer hardware and software to perform in-house computer data processing efficiently and effectively.

According to a 1985 computer utilization survey, the contractors who purchased computers were relying almost exclusively on commercially available software that perform accounting functions related to payroll, general ledger, accounts payable/receivable, and job cost. Contractors in general, however, were concerned about the constraint on flexibility and the compatibility of the pre-written application software packages with their in-house procedures. Most of the contractors were somewhat reluctant to develop their own source code computer programs, to meet the in-house procedures. To overcome these problems, a data processing systems which make use of an integrated package are proposed. With this approach, construction contractors with little or no computer data processing experience can now solve a wide range of construction-related problems with computer convenience, speed, accuracy, and flexibility. The integrated package commands and functions can be mastered in far less time than required in learning programming languages such as BASIC or FORTRAN.

The specifications, estimating, forecasting, design, bidding, cash flow analysis, management control system, material management, equipment replacement analysis, and owning & operating costs of construction equipment modules developed and presented in this thesis demonstrate the versatility of using integrated packages in the construction industry. Program solutions such as those presented could be formulated by any construction contractor to fit his own unique in-house procedures. The capability to solve problems such as these can be purchased for as little as $3,200 for a professional 256K microcomputer, including a dot-matrix printer, and $300 for the integrated software package such as Lotus 1-2-3.

The other outcome of the computer utilization survey was the identification of the causes of resistance to computer use in the construction industry. The common reason was found to be the inability of the small contractors to justify computer purchase because of their small annual contract volume. The lack of fundamental computer knowledge of the contractors was also revealed. As mentioned before, the system suggested in this study can be purchased for as little as $3,500, and certainly will be in the reach of even small size contractors irrespective of their contract volumes. To facilitate the use of computer, the criteria for the selection of a computer system are presented. These criteria are proposed to familiarize the contractors with available hardware/software and their selection procedures. The criteria also outline the pre-implementation procedures and specific recommendations for the computerization of organizational procedures.

Contributions from any research work are normally identified under two major categories; first, advancement of the state of the art in the relevant field and second, practical use of the work. This study contributes to both categories.

1. The state of the art has been advanced by:-

   a. Analyzing the current trends in computer utilization in the construction industry based on the actual feedback from the construction contractors.

   b. Introducing the use of integrated packages for the construction management functions through various models.

   c. Illustrating the capabilities of graphical presentation of construction management functions with the use of integrated packages. Very few, if any, currently available application software provide this facility of presenting the results graphically.

   d. Formulating a set of criteria for the selection of complete computer systems by construction contractors.

2. Practical uses of the research are:-

   a. The modules developed for construction management functions in this study are based on actual feedback from construction contractors, therefore, these models can be utilized in real life situations without any modifications.

   b. Some of the modules were demonstrated to construction and engineering personnel at continuing engineering education seminars at Memorial University of Newfoundland. The power and versatility of the integrated packages for the use of the construction industry were appreciated at these seminars. The constructive criticism solicited were incorporated into the modules to enhance their practicability.

   c. Special emphasis was given to explain the concept and procedures of structuring the modules on ar integrated package.

This will assist the users to easily develop their own modules to suit their specific algorithms.

d. The criteria for the selection of a complete computer system can be used by the contractors with little or no knowledge of electronic data processing.

e. The results of the study can be used by contractors as a starting point for computerization, or extending computer use outside traditional accounting and bookkeeping areas. Moreover, software vendors can refer to this study to find out the problems faced by contractors in implementing the commercially available software developed specifically for the construction industry, and necessary improvements can be made.

Although there is a growing trend in computer utilization in the construction industry, the extent and the rate of growth is minimal, compared to the availability of the new technology. This result is consistant with the generally held view that technology transfer in the construction industry lags far behind any other industry in Canada [12].

The computer utilization survey and other such studies revealed the problems faced by the construction contractors in implementing and extending computer use in the construction industry. To solve these problems a system is suggested which makes use of the new developments in the computer industry. The next step in enhancing computer implementation in the construction industry is the transfer of this system to the industry. In this regard, there are significant implications in the participation of government R&D agencies and of educational institutions, which usually transfer new technology to the industry. As contractors become more computer oriented, computer applications in the construction industry will become more commonplace.

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APPENDIX A

COMPUTER UTILIZATION SURVEY QUESTIONNAIRE

COMPUTER USAGE QUESTIONNAIRE FOR CONSTRUCTION CONTRACTORS

INSTRUCTIONS:

All contractors are requested to complete Part I below.

Contractors with in-house computer facilities are requested to complete Part II.

Contractors utilizing a computer service bureau, computer consultants, etc. are requested to complete Part III.

Please mail the completed questionnaire forms to:

Prof. W.J. Campbell
Engineering & Applied Science
Memorial Univ. of Nfld.
St. John's, Nfld., Canada
A1B 3X5

Would you like to have the Survey Report ☐ Yes ☐ No

PART I GENERAL INFORMATION

Firm name: ______
Address: ______
Telephone: ______
Name of person completing questionnaire: ______
Construction specialty of the firm: ______
Number of permanent employees: ______
Number of permanent clerical employees: ______
Number of T4 forms filed in 1984: ______
Appx. contract volume, 1984: ______

Does your firm have its own computer?

☐ Yes ☐ No

If yes, complete Part II.

Does your firm utilize service bureau, leased time or consulting services?

☐ Yes ☐ No

If yes, please complete Part III, (one copy for each service to which you currently subscribe or for which you have recent experience).

If your firm does not use computers or computer services in any way, check the box(es) that apply:

☐ Computers and/or services are too expensive

☐ Company volume does not justify the expense

☐ Computer software are not compatible with in-house procedures

☐ Company is considering the following options

______
______
______
______

☐ We need additional information before deciding which computers and/or services would be appropriate. In particular we need information pertaining to the following: ______
______
______
______

A. Hardware.

1. Computer manufacture and model: ____________________

2. Date of delivery: ____________________

3. Size: ☐ micro ☐ mini ☐ main frame

4. Main memory: ____________________ k-byte

5. Mass storage:

☐ ____________________ floppy disk

☐ ____________________ hard disk

☐ ____________________ tape

☐ ____________________ other

6. ☐ Purchased ☐ Leased ☐ Other

7. Brief description of input/output devices

____

____

____

____

B. Application Software. Indicate types of software packages you have used and rate their usefulness. Fill in the vendor name and address; write "in-house" if the program was written by your own personnel.

1. ☐ Payroll: ____________________

☐ excellent ☐ good ☐ acceptable ☐ poor

2. ☐ General ledger: ____________________

☐ excellent ☐ good ☐ acceptable ☐ poor

3. ☐ Accounts Payable/Receivable: ____________________

☐ excellent ☐ good ☐ acceptable ☐ poor

4. ☐ Word Processing: ____________________

☐ excellent ☐ good ☐ acceptable ☐ poor

5. ☐ CPM Scheduling: ____________________

☐ excellent ☐ good ☐ acceptable ☐ poor

6. ☐ Project cost Acct.: ____________________

☐ excellent ☐ good ☐ acceptable ☐ poor

7. ☐ Estimating: ____________________

☐ excellent ☐ good ☐ acceptable ☐ poor

8. ☐ CAD & Drafting: ____________________

☐ excellent ☐ good ☐ acceptable ☐ poor

C. Comments: Please comment on the time and/or savings you have experienced as a result of your computer acquisition.

____

____

____

Is the hardware described above adequate for your operation? ___

____

Are you satisfied with the systems software supplied by your vendor? ____________________

____

Has system service been satisfactory? ____________________

____

Part III SERVICE BUREAUS AND COMPUTER PROCESSING TASKS PERFORMED BY REMOTE FACILITIES OR OUTSIDE CONSULTANTS (Please execute one form for each bureau or consultant)

A. General.

1. Name and address of service bureau, company or consultant: ________

2. Input media (terminal, punched cards, mailed data, etc.): ________

3. Output media (CRT, printer, plots, etc.) ________

4. Average time for processing ________

B. Application software and subjective rating.

☐ Payroll	☐ Excellent	☐ Good	☐ Acceptable	☐ Poor
☐ General Ledger	☐ Excellent	☐ Good	☐ Acceptable	☐ Poor
☐ Accounts Payable/Receivable	☐ Excellent	☐ Good	☐ Acceptable	☐ Poor
☐ Word Processing	☐ Excellent	☐ Good	☐ Acceptable	☐ Poor
☐ CPM Scheduling	☐ Excellent	☐ Good	☐ Acceptable	☐ Poor
☐ Project Cost Acct.	☐ Excellent	☐ Good	☐ Acceptable	☐ Poor
☐ Estimating	☐ Excellent	☐ Good	☐ Acceptable	☐ Poor
☐ CAD & Drafting	☐ Excellent	☐ Good	☐ Acceptable	☐ Poor

C. Comments. Please comment on the overall cost effectiveness of the service described above. ________

D. Future plans. Comment on your plans to expand or suspend the service described above. ________

APPENDIX B

POPULAR INTEGRATED SOFTWARE PACKAGES

FEATURES

	PRODUCT: Aladin	Aura	Corporate MBA	Electric Desk
Spreadsheet	Y	Y	Y	Y
Word processing	Interface only	Y	Y	Y
Database	Y	Y	Y	Y
Graphics	Y	Y	Y	N
Communications	N	N	Y	Y
Spelling check	N	N	N	N
Price	$595	$495	$895	$345
Minimum memory	128K	256K	384K	256K (128K PCjr)
Disk Tutorial	Y	Y	Y	Examples
Easy to learn?	No		Good	Very easy
Spreadsheet features	Calc/database			
Matrix format		295x63xN	999x95	255x255
Recalc 2500 cells	Could not run	1:55	3.08	00 48
Windows	N	2	4	2
Variable width columns		Y (1-35)	Y (3-99)	Y
Data alignment	(The Calc	LRC	LRC	LRC
Log functions	function	3	2	0
Trig functions	was too	7	6	0
Statistics functions	poorly	7	3	5
Date functions	documented	5	0	N
Financial functions	to answer	5	3	5
IF THEN		Y	Y	Y
Replicate and copy		Y	Y	Y (*Very easy*)
Sort rows and columns		Y	Rows	N
Search and replace		Y	N	N
Iteration		Y	N	Y
Macros		Advanced	Advanced	N
Table lookup		Y	Y	N
Word Processing Functions	"Bridge" only			
Query replace		Y	N	N
Ignore case in search		N	N	N
Headers and Footers		Y	N	Y
Merge files		Y	Y	Y
Customize printer		Limited	Y	Y (easy)
Form letters		Y	Y	Y
Typeover and Insert		Y	Y	Y
OK for fast typists?		Y	Y	Very good
Database Functions				
Files too large for memory	Y	Y	N	Y
Spreadsheet format	N	In spreadsheet	Y	N
Records per file	65,535	(Disk size)	999	65,000
Fields per record	512	256	95	50
Maximum field	4K per record	255	254	1,000
Number of sort keys	1	9	6	1
Calculated fields	Y	Y	Y	N
Command language	N	N	Macros	For search only
Screen generator	Y	Y	Y	Y
Report generator	Y	Y	N	Minimal
Index type	B-StarPlus Tree	B-Tree	None	B-Tree
Graphics Functions				None
Move labels	N	Limited	N	
Bar charts	Y	Y	Y	
Pie charts	N	Y	Y	
3D Bar charts	N	Y	N	
Line chart	N	Y	Y	
Customize printer graphics?	N	(IBM/Epson)	Y	
Use plotter?	N	HP 7475	Y	

Encore!	IBM Assistant	InteSoft	ITSoftware	Jack 2	Jane	KnowledgeMan
Y	(due 1985)	InteCalc	Calcit	Y	Y	Y
Limited	Writing Asst	InteWord	Writit	Y	Y	N
Special purpose	Filing/Report	InteBase	Keeplt	Y	Y	Y
Y	Graphing Asst	InteGraph	Showlt	Y	N	KGraph/KPaint
N	N	N	Linklt, Passlt	N	N	N
N	Y	N	in Writlt	N	N	N
$695	$150 each	$295 each	$100–$500 each	$495	$179	$500
256K	128K	128K	256K	256K	48K	192K
Y	Samplers	N	Y	Y	Animated help	?
Good	N	Fair to good	Very good	Good	Very easy	Not tested
	Planning Asst.	InteCalc	Calcit	(In database)		
32,000 cells		255x255x255	255x255x255	255x255	5x14	255x255
00:21/2,000 cells	(To be released	00:08	00:08	00:10/1,000 cells	(only 70 cells)	Not tested
1	next year)	4	4	2	4	N
Y		Y (1–127)	Y	Y	N	Y
None		L R	L R CHar CVer	L R	L R C	?
4		2	3	1	N	3
0		6	8	N	N	Y
0		7	10	2	5	7
2		4	2	N	N	N
8		11	11	2	N	N
Y		Y	In Exec only	Y	N	If Then Else
Y		Replicate only	Y	N	Cut and paste	Y
Y		N	N	N	N	Use database
N		N	N	Forms only	N	Y
Y		Y	Y	N	N	N
Advanced		Exec functions	Exec	N	N	Y
Y		3 functions	Y (4 functions)	Y	N	Y
(UCSD editor)	Writing Assist	InteWord	(Multimate)			None
Y	Y	Y	Y	Y	Y	
Y	N	Y	Y	Y	Y	
Y	Y	Y	Y	Y	Title only	
Y	Y	Y	Y	Y	Y	
Parallel/serial	Y	Y	Y (60 options)	Y	6 printers	
N	Y	Y	Y	Y	Manually	
Y	Y	Y	Y	Y	Y	
N (line editor)	Y	Fair	Y	Y	Probably not	
(Specialized)	Filing Assist	InteBase	Keepl.			
N	Y		Y	Y	Not stated	Y
Y	N		N	Possible	N	Optional
1	29,500		Disk size	2,200	Not stated	65,535
1,024	31 pages of 100		99	1,024	10	255
255	Not specified	(InteBase is not yet available)	70	255	25	65,535
1	1		9	3	1	More than 10
Y	Max 3 in report		Y	Y	N	Y
Advanced	N		Y	N	N	Y
N	Y		Y	Y	N	Y
Y	Reporting Asst		Y	N	N	Y
None	None		3 unspecified	None	None	B-Plus Tree
	Graphing Asst	(In InteCalc)	Showlt		None	
Y	N	Y	N	Y		Y
Y	Y	Y	Y	Y		Y
Y	Y	N	Y	N		Y
N	N	N	N	N		Y
Y	Y	N	Y	Y		Y
Epson only	9 choices	N	N (Epson/IBM)	N		Y
HP only	5 choices	N	HP IBM, CalComp	N		?

FEATURES

PRODUCT:	Offix	1-2-3	PeachText 5000	PractiCalc II
Spreadsheet	N	Y	Y	Y
Word processing	Y	N	Y	Limited
Database	Y	Y	Y	Y
Graphics	N	Y	Y	Y
Communications	N	N	Y	N
Spelling check	N	N	Y	N
Price	$149	$495	$395	$69 95
Minimum memory	192K	192K	128K	48K
Disk Tutorial	N	Y	(Sample data)	N
Easy to learn?	Fair	Good	Fair to good	Y
Spreadsheet features	None			
Matrix format		256x2048	63x254	250x100
Recalc 2500 cells		00 15	1 06	00 11/1700 cells
Windows		2	2	N
Variable width columns		Y (1-72)	Y (1-99	Y 1-38
Date alignment		L R C	L R	L R
Log functions		3	3	2
Trig functions		7	7	4
Statistics functions		7	5	0
Date functions		5	0	0
Financial functions		5	1	0
IF THEN		Y	Y	Y
Replicate and copy		Y	Copy 11 only	Y
Sort rows and columns		Rows	N	Columns
Search and replace		Search	N	Search
Iteration		Y	N	N
Macros		Y	N	N
Table lookup		Y	Y	N
Word Processing Functions		None		Very minimal
Query replace	N		N	N
Ignore case in search	N		N	Y
Headers and Footers	N		Y	N
Merge files	Y		Y	N
Customize printer	N		Y	N
Form letters	Y		Y	N
Typeover and Insert	Y		Y	Replace
OK for fast typists?	N		Y	N
Database Functions			List Manager	
Files too large for memory	Y	N	[illegible]	N
Spreadsheet format	N	Y	N	Y
Records per file	1 million char	Unspecified	32 765	Memory size
Fields per record	250	32-256	14	Memory size!
Maximum field	250	240	75	38
Number of sort keys	1	2	[illegible]	1
Calculated fields	Y	Y	N	Y
Command language	N	Keyboard macros	N	N
Screen generator	Y	N	N	N
Report generator	Y	N	[illegible]	N
Index type		None	None	None
Graphics Functions	None		None	
Move labels		N		N
Bar charts		Y		Y
Pie charts		Y		N
3D Bar charts		N		N
Line chart		Y		N
Customize printer graphics?		Epson/Prism		N
Use plotter?		HP 7470A		N

Series One Plus	Symphony	T/Maker	HI EZ Pieces (Apple Works)	The Ultimate	Window Master
Y	Y	Y	Y	N	Magic Worksheet
Y	Y	Y	Y	Y	Word Right
Y	Y	Y	Y	Y	NAD & Analyst
ExecuPlot	Y	Bar charts	Graph'n'Calc	N	Y
ExecuLink	Y	N	Promised	ECOM only	N
N	N	Y	N	Y	N
$495 (WP DB SS)	$695	$450		$250	$495 (complete)
192K	320K	128K	128K	96K	256K
Y	Y	Y (demo disk)	Y	N	N
Acceptable	Good	Difficult	Y	Easy	Very difficult
ExecuModel				None	Magic Worksheet
256x64	256x8191	50 x (memory)	127x999		64x255
00 55/1,450 cells	00 05/2,125 cells	Could not run	00 40		3 45
2	4	N	2		2 (H or V)
Y (1-72)	Y (1-240)	Y (free form)	Y (2-75)		Y (3-77)
L R	L R C	L R C	L R C		L R C
3	3	3	0		3
Pi only	7	4	0		7
5	7	4	2		2
0	11	Simulated	0		0
NPV only	5	NPV	2		NPV
Y	Y	Y	Y		N
Y	Y	N	Y		Y
N	Y	Y	N		N
N	Find	Y	Search		Y
N	Y	N	N		N
N	Y	N	N		Scripts
N	Y	Simulated	[illegible]		Y
					Word Right
Y	Y	Y	Y	Y	Y
Y	Y	N	Y	N	Y
Y	Y	Y	Y	Footers	Y
Y	Y	Y	NM	Y	Y
Y	Y	Y	Y	Some	Y
Y	Y	Y	N	Y	Y (with NAD)
Line insert	Y	Y	Y	Y	Y
Fair	Y	N (Line editor)	[illegible]	Fair	Could not test
					Analyst
Y	N	Y	N	Y	[illegible]
N	Y	Optional	Y	N	N
Unspecified	8,192	About 800	(Memory size)	(Disk size)	Disk size
35	256	About 20-100	30	250	50
78	239	80	79	76	132 (total 255)
5	3	1	1	9	1
In reports only	Y (sheet mode)	Y	Y	N	Y
N	Y	N	N	N	Script
Y	Y	Uses editor	N	N	N
ExecuReporter	Y	Y	Y	Form Letters	Y
Index file	None	Not specified	None	None	Not mentioned
ExecuPlot			None	None	
N	Y	N			N
Y	Y	Y			[illegible]
Y	Y	N			Y
N	N	N			N
Y	Y	N			Y
Epson only	Y	N			Not described
N	Y	N			HP7470A only

APPENDIX-C

RETAINING WALL DESIGN CALCULATIONS

A properly designed retaining wall must satisfy two requirements. First, to make the structure safe against failure by overturning and excessive settlement, the pressure beneath the base must not exceed the allowable soil pressure; furthermore, the structure as a whole must have an adequate factor of safety with respect to sliding along its base or along some weak stratum below its base. Second, the entire structure as well as each of its parts must possess adequate strength.

In the Lotus 1-2-3 design module , shown in section 3-5, standard principles of soil mechanics and reinforced concrete design are applied. The lateral earth pressure is based on Rankine's formulas [15,30]. A step by step design procedure is described below.

A cantilever retaining wall as shown in Figure 1 is considered as an example. The input data required for the design are:

For Fill: Gamma1, Phi1, and Cohesion (C1)

For Original Soil: Gamma2, Phi2, and Cohesion (C2)

For Concrete : Gamma3 and Concrete Strength (Fc)

Other inputs are: Allowable soil pressure (qa), Reinforced steel strength (Fy), Surcharge (Q), Soil height at heel (H), soil height at toe (h), and the dimensions of wall and footings are as shown in Figure 1.

The coefficient of active earth pressure "Ka" and "Ka'" for soil are calculated using the following equations:

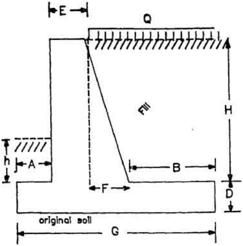

Figure 1: Cantilever Retaining Wall

$$Ka = \frac{1\text{-Sin(Phi1)}}{1\text{+Sin(Phi1)}}$$

and,

$$Ka' = \frac{(\text{Gamma1})(H)(Ka)\text{-}(2)(C1)(Ka)^{0.5}}{(\text{Gamma1})(H)(Ka)}$$

Active earth pressure(Pa) is computed as:

$$Pa = [(0.5)(\text{Gamma1})(H+D)^2(Q)(H+D)](Ka')$$

"Fv" and the sum of moments to resist overturning "Mr" are caculated in tabular form with reference to Figure 2

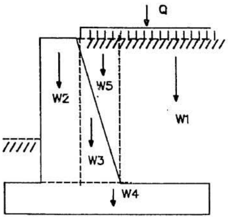

Figure 2: Forces on Retaining Wall

PART	WT.OF PART (KN)	ARM (M)	MOMENT (KN.m)
	(1)	(2)	(1)*(2)
1	(B)(Q)+(H)(B)(Gamma1)	(G)-(B/2)	
2	(Gammac)(E)(H)	(A)+(E/2)	
3	(F)[(H)(0.5)(GammaC)]	(A)+(E)+(2F/3)	
4	(G)(D)(GammaC)	(G/2)	
5	(F)(H)(0.5)(Gamma1)	(A)+(E)+(F/3)	
6	(F)(Q)	(A)+(E)+(F/2)	

Fv = K Mr = KN.m

The sum of overturning moments "Mo" and the sum of driving forces "Fd" are calculated as:

$Mo=(0.5)(Gamma1)(H+D)^2(Ka')[(H+D)/3]+(Q)(H+D)(Ka')[(H+D)/2]$

$Fd=(0.5)(Gamma1)(H+D)^2(Ka')+(Q)(H+D)(Ka')$

The sum of the resitive force (Fr) is computed by the following procedure:

adhesion (C') = 0.67 C

& Fr = (C')(G)+(Fv)(Tan(Phi2))

The overturning safety factor is Mr/Mo and sliding safety factor is Fr/Fd . For safe design both safety factor should be greater than 2. Otherwise, wall and footing dimensions should be changed.

Soil bearing pressure calculations are:

Net moment (M) = Mr-Mo
Distance from toe (x) = M/Fv
eccentricity (e) = (G/2)-x

Eccentricity should be less than G/6, otherwise dimensions should be changed.

Maximum soil pressure (qmax) and minimum soil pressure (qmin) are calculated as follows.

qmax = (Fv/G)[1+(6e/G)]

qmin = (FV/G)[1-(6e/G)]

"qmax" and "qmin" should be less than allowable soil pressure "qa".

Rebar design calculations for stem, toe, and heal are as follows:

FOR STEM:

at base

Ultimate moment $(Mm)=(0.5)(Gamma1)(H+D)^2(Ka')[(H+D)/3] +(Q)(H+D)(Ka')[(H+D)/2]$

Required Ru = $(Mm)/(B)(E+F)^2$ (1)

m = (Fy)/(0.85)(Fc) (2)

Reinforcement ratio$(Row)=(1/m)[1-(1-(2.m.Ru/Fy))^{0.5}]$ (3)

Area steel = (Row)(E+F)$(10)^4$ sq.cm/m (4)

at mid height

Ultimate moment (Mm)=(0.5)(Gamma1)$(H+D)^2$(Ka')[(H+D)/6]
+(Q)[(H+D)/2](Ka')[(H+D)/4]

Required Ru = (Mm)/(b)$(E+(F/2))^2$

The values of "Row" and "Area steel" are calculated by using equations (3) and (4).

FOR FOOTING:

at toe section

Shear stress check:

$$\frac{x}{qmax - qmin} = \frac{G(A-D)}{G}$$

$$V = \frac{qmax + (qmin + x)}{2} \cdot (A - D)$$

Vu = (1.7)(V) kN/sq.m

Now,
Phi Vc = (.85))(2)$(Fc)^{0.5}$ (b)(D)

"Phi Vc" should be greater than "Vu", if not, the dimension of "D" are changed as follows:

D(new) = D(old).(Vu)/(Phi Vc) (5)

Bending moment calculations:

q1 = (qmax - qmin)(B + E + F)/(G)

q2 = qmax -q1

Moment at toe "Mt"=(q1)(A)(A/2)+(0.5)(q2)(A)(2A/3)

$Mu = 1.7\ Mt$

$Ru = Mu/D^2$ KN/sq.m

"m", "Row", and "Area steel" are calculated by using equations (2), (3), and (4) respectively.

at heel section

Shear stress check:

$V = (Gamma1)(H)(B\text{-}D)$

$Vu = (1.4)(V)$

"Phi Vc" should be greater than "Vu". otherwise the dimension "D" are changed by using the eq. (5).

Bending moment calculations:

Moment at heel "Mh" $=(0.5)(Gamma1)(H)(B)^2$

$Mu = (1.4)(Mh)$

$Ru = (Mu)/(D)^2$

"m", "Row", and "Area steel" are calculated by using equations (2), (3), and (4) respectively.

The horizontal steel required for wall and footing are calculated as follows:

for wall

$$\text{Area steel} = \frac{(2)(Fc)^{0.5}}{Fy} (E+F)(10)^4 \quad \text{sq.cm/m}$$

for footing

$$\text{Area steel} = \frac{(2)(Fc)^{0.5}}{Fy} (D)(10)^4 \quad \text{sq.cm/m}$$

APPENDIX D

EQUIPMENT OWNING & OPERATING COST

Equipment costs are divided into ownership costs and operating costs. The method of calculation for both costs is explained as follows:

OWNERSHIP COST CALCULATIONS: Equipment owning costs are divided into the categories: depreciation, interest, taxes, insurance, storage and miscellaneous.

Depreciation is the decrease in the value of the equipment due to age and use. The amount to be depreciated is based on the initial total cost of the equipment less the value of its most wearable parts. The cost of most wearable parts are included in the equipment operating costs. There are a number of methods for calculating depreciation. However, three most commonly used methods (straight line, double declining balance, and the sum-of-the-years-digits method) are included in the module.

Interest is the charge for borrowed money or the return for the money invested. If the interest charge is not known it can be assumed as 10 to 15% of the average book value of the equipment for any year during the useful life of the equipment [13]. The average book value (ABV) of the equipment in any year(i) is calculated by the following expression:

$$ABV(\text{any year } i) = 0.5(BV_{i-1} - BV_i)$$

where BV_i is the equipment book value for any year (i) during useful life of the equipment and is computed as:

Book value(u<i>1) = Book value(i-1)- Depreciation(i)

Where "u" is the useful life of the equipment.

Book value(i=0) = Total cost of the equipment less tires when applicable.

Taxes are costs charged by the federal or provincial governments based on the ownership of the equipment. This charge is commonly varied between 1 to 5% of the average book value of the equipment for any year of its useful life [13].

Insurance is the premium paid by the owner to recover financial loss in case of loss of or damage to the equipment. This annual charge varies between 1 to 3% of the average book value of the equipment [13].

Storage and miscellaneous costs represent the cost of storage space, facilities, and labor used to protect the equipment when it is not on a job. This charge is usually 1 to 5% of the average book value of the equipment [13].

The total cost of equipment ownership is found by adding the above categories of the costs. These costs are computed on an annual basis and then reduced to an hourly basis by dividing the estimated number of operating hours during the year.

OPERATING COSTS CALCULATIONS: Equipment operating costs are divided into the following categories [13,28,31].

1- Fuel consumption costs

2- Service costs

3- Major repairs costs

4- Tires replacement costs

5- Tires repaires costs

Fuel Consumption Costs: The fuel consumption cost is found by multiplying the equipment's fuel consumption by the cost of the fuel. The most accurate method for determining these costs is the actual measurement of fuel consumption under similar job conditions. However, when estimates are required, the following method may be used [28]:

- Estimate full fuel load consumption of the equipment.

Full load fuel consumption(FFC) = 0.06 x Break Horse Power(BHP)

- Multiply the value obtained in step 1 by the Equipment Load Factor which is given in Table 1 (Figure 3-41). This conversion is needed because the equipment rarely works under full load conditions.

Service Costs: These costs represent the cost of lubricant, hydraulic oils, filters, and labor required for routine maintenance of the piece of equipment. Generally, these costs are provided by the equipment manufacturer and then these costs are adjusted for the expected operating conditions of the equipment. However, if this information are not available, an estimate of hourly service costs can be made using the following equation [28]:

Service Cost = Service factor * Fuel Consumption cost

A table of Service factors under different operating conditions is provided in the computer module (Table 2 in Figure 3-41).

Major Repairs Costs: Major repair costs result from the major repairs or replacement of parts and from overhauling the piece of equipment. Such a charge is not expected to be a regular amount each year, but tends to increase with the age of the equipment. Records kept of the cost of these charges during the life of a particular or similar type of equipment indicate the proportionate expense to anticipate. When the information required for estimating the costs for major repairs of the equipment are not available, the following method may be used [28]:

- Compute the total repairs cost "R" by multiplying the total cost of the equipment by the repairs factor. The repairs factor is provided in the Table 3 (Table 3 is in Figure 3-41).

- Compute the yearly repairs cost as follows:

Repairs cost (year i) = (i/Sd) x R

Where i = Any year during the equipment life

Sd = Sum of digits in the useful life

Tire Replacement Costs: The cost of tire replacement is another major item of expense for rubber-tired equipment. Hourly tire replacement costs are obtained by dividing the cost of a new set of tires by tire life. If adequate records for estimating tire life are not available, an estimate can be made by using the Typical Tire Life table provided in the Computer module (Table 4 in Figure 3-41)

Tire Repairs Costs: These costs are estimated as a percentage of tire replacement costs.