1972

Preliminary overview of hardware costs for minicomputer use in computer-assisted instruction

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A PRELIMINARY OVERVIEW OF HARDWARE COSTS FOR MINICOMPUTER USE IN COMPUTER-ASSISTED INSTRUCTION

by

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B.A., University of Montana, 1970

Presented in partial fulfillment of the requirements for the

degree of

Master of Arts

UNIVERSITY OF MONTANA

1972

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Mar 15, 1972
Date

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1-29-73

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CHAPTER I

INTRODUCTION

Background

The concept of computer-assisted instruction (CAI) was developed only fifteen years ago; it has since become a working reality. The rapid growth of computer-assisted instruction also parallels an equally rapid growth in the area of electronic data processing.

The increase in computer usage has occurred in three separate, on-going stages.[1] The first machines were used for solving various mathematical, scientific, and engineering problems at major universities and research centers. This primary usage continues, but has been overshadowed by the use of computers in the bookkeeping, record storing, and general accounting required in business and industry.

This secondary usage of electronic data processing in industry and commerce has had a great influence on the business of the nation over the last ten to fifteen years, as has been indicated by the increasing number of machines used in these areas. The third area of computer usage is in interaction with people: the development of artificial intelligence (programming the computer to use English or other languages

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[1]Don D. Bushnell, "Computer Based Instructional Systems," Automated Education Handbook, ed. Edith Harwith Goodman (Detroit: Automated Education Center, 1965).

as a medium for retrieving data and answering questions), automatic abstracting and indexing (as in the handling of library materials), and the use of computer-assisted instruction are all examples of various recent developments.

Atkinson and Wilson have isolated two factors which have contributed greatly to the growing use of computers in teaching. Perhaps the most important early influence they noticed was Skinner's work, which focused educators' attention on individualized instruction.[2] As a result of this influence, the programmed text and other programmed learning aids (such as the early teaching machines) were devised. Unfortunately, programmed learning in practice fell short of the great things originally predicted for it. This situation still left certain educators with a sense of "rising expectations"; the general feeling among them was that through the use of science and special technology the instructional process might be altered to suit the individual abilities and motives of a wide variety of students.[3]

The second major influence was the introduction of the time-sharing concept for computers, which allowed many students to use the same machine at one time. Only with the more recent machines did the idea of time-sharing become practicable. The possibility of many people being able to use the same machine simultaneously (thus allowing an

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[2]R.C. Atkinson and H.A. Wilson, "Computer Assisted Instruction," Computer Assisted Instruction. A Book of Readings, eds. Richard C. Atkinson and H.A. Wilson (New York: Academic Press, Inc., 1969), p.3. For a further examination of Skinner's work see B.F. Skinner, The Technology of Teaching (New York: Appleton-Century-Crofts, 1968).

[3]Atkinson and Wilson.

increased number of students to benefit from an individual lesson at one time) made the benefits of computer-assisted instruction even more evident. Using programmed learning in conjunction with time-share computers, computer-assisted instruction became a reality.

Although the technology was then present, a single factor still impeded the greater use of CAI -- and still does today -- the expense of buying, leasing and operating large-scale time-share computers. Costs are coming down for all types of computer systems, however. The National Science Foundation (and a number of other governmental and private agencies) has supported research in the area of automated instruction. Without massive financial assistance, the concept of computer-assisted instruction would probably have been permanently relegated to obscure references in the technical journals.

Purpose of the Study

The current systems of computer-assisted instruction are costly; ways must be found to reduce this expense if this innovative educational tool is to be used effectively in most schools.[4] One possible solution is through the use of the minicomputer which is a recent development in the computer field that was brought about by new methods of miniaturization and cost reduction.

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[4]D. Jamison, P. Suppes, and Cornelius Butler, "Estimated Costs of Computer Assisted Instruction for Compensatory Education in Urban Areas," Educational Technology, Vol. X, No. 9 (September 1970), pp. 49-57.

The Hewlett-Packard Corporation has been marketing CAI systems for some time, using their own line of minicomputers; the Digital Equipment Corporation also has systems designed for education based on the use of minicomputers. It should be noted, however, that elaborate forms of CAI -- beyond the simple student-terminal level -- may require a larger or more powerful computer.

If minicomputers are to have a greater role in computer-assisted instruction, one major question must be answered affirmatively. Can the small-scale computers operate adequately at a significantly lesser cost than do the larger systems used presently? The possibility does exist that the special equipment required to enable minicomputers to successfully handle CAI would eliminate any cost advantages of the smaller systems; if minicomputers were found to offer little or no cost advantages over the larger systems in current use, there would be little reason to consider small-scale computers for CAI use.

In this study, the costs of representative lines of various computers will be investigated to determine if a cost advantage does exist in using minicomputers as opposed to the larger, more generally used machines. The costs for various minicomputer central processing units from several manufacturers will be investigated for comparative purposes.

Statement of the Problem

In this study, an attempt will be made to give a general cost picture for the hardware required (that is the equipment needed) when a minicomputer system is considered for computer-assisted instruction. By

examining a representative line of computers, both large-scale system costs and minicomputer costs will be compared in order to determine any financial savings that would result from the use of minicomputers as opposed to the use of the more generally used, large-scale systems.

Definition of Terms

Computer-assisted instruction or computer-administered instruction (CAI): For the purposes of this study, this is defined as the use of a computer to supervise a lesson or drill that has been prepared in advance by an educator/programmer. The lesson is presented on a one-to-one basis between the machine and the student. Even though the computer may be handling a large number of students at once, each student is receiving individual attention at his terminal.

Time-share computer: This is a computer that is able to process a number of different programs at the same time, on a rotation basis. The machine does the first step of the first program, then the first step of the second program, and so on until all the terminals have been cycled through their first step; the process then continues with the second step for each program. This happens on a sequential basis at such great speed that the appearance is one of many different programs being handled simultaneously.

Minicomputer: This is a small machine, often "bread box" size, that is capable of handling many of the same problems as a large size computer, only on a smaller scale. Some minicomputers can handle time-share; however, they are limited to a maximum of about sixteen terminals. As a rule, a minicomputer central processing unit (CPU) costs under $20,000.00.

Terminal: This is a typewriter that is connected to the computer for the purpose of machine-user communication. Through the typewriter, information is both received from the student and transmitted from the computer.

Program: This is a set of instructions stored in the computer that control what the machine does. A CAI lesson is a form of a program, similar to a programmed text.

Programmer: This is a person who writes programs. In the case of CAI this person would be an educator preparing a structured lesson to be presented by the computer.

Machine operator: This is the person who oversees the operation of the entire computer.

Disks, tapes and drums: These are auxiliary storage devices used with computers to increase memory capacity and to facilitate time-share operation.

Central processing unit (CPU): This is the foundation of the computer system; the CPU is the basic computer with no accessories.

Peripherals: This is any accessory used with the CPU to make up a computer system.

Hardware: Any mechanical item such as the CPU, disks, or terminals are termed hardware.

Software: Any program or set of instructions for a computer is included under software.

Keyed audio tapes: These are tapes that are recordings of a human voice giving verbal instructions to the student at various times through a CAI lesson.

Random access video displays: Similar to audio tapes, these tapes include various pictures that are displayed on a cathode ray tube or viewing screen.

Cathode ray tube or terminal (CRT): This is simply a TV picture tube that is hooked up to the computer in order to present numbers, words, or pictures on demand.

Paper tape reader: This is a piece of hardware that feeds the initial CAI program into the computer at a rapid enough rate to avoid the wasting of machine time.

Disk controller: This hardware allows a disk memory to be attached to the CPU.

8K core storage: This is a term for the eight thousand memory storage locations which may be used to increase the capacity of the CPU.

Boot strap loader: This program facilitates the loading of CAI programs into the computer.

Real time clock: This clock is used to determine how much use a computer component has had at any given point in time.

Assumptions

1. The costs found in the various journals and computer company literature are the true costs to be expected.
2. The machines investigated will perform as described by the various computer companies' literature.
3. The costs for both minicomputers and large-scale machines will rise or fall at the same rate.
4. Software costs and personnel (machine operator) costs are

similar for both minicomputers and large-scale systems if used similarly.

5. Computer-assisted instruction is superior to conventional teaching methods as a means of providing individualized instruction.

Limitations

1. For this study, computer-assisted instruction will be limited to that which can be accomplished with a computer and teletype terminal, excluding any audio or visual peripherals such as keyed audio tapes or random access video displays; cathode ray terminals (CRTs) will also be excluded.
2. Cost and utility information will be limited to that which is available through published sources or through informal discussions with known users of this equipment.
3. Software and personnel costs will be excluded due to the wide cost variations possible in this area.
4. The costs shown in print may no longer be accurate or up to date.
5. The costs of the building modifications necessitated by installing a computer cannot be included.

CHAPTER II

A REVIEW OF THE LITERATURE

A great deal has been written about computer-assisted instruction -- studies to determine the effectiveness of CAI have been done, programs have been written, the role of computers in instruction has been explored, the desirability of individualized instruction has been examined and the philosophies of educational technology have also been delineated. These are all interesting, relevant topics, but they are not within the scope of this study. The computer field is relatively new; references to the specific use of minicomputers for CAI are difficult to find other than an occasional mention that minicomputers on account of their specialized nature, might be a possible medium for individualized instruction.[1]

A justification for the search for a lower-priced system can be found, however. Kopstein and Seidel reported that at the present levels of technology, CAI costs are at least ten times that of traditionally administered instruction.[2] This means that for CAI to be as cost-effective as are current teaching practices, it would have to be

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[1]Datapro Research Corporation, All About Minicomputers, reprinted from June 1971 Supplement to Datapro 70 (1971 Edition).

[2]Felix F. Kopstein and Robert J. Seidel, "Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics, "Computer Assisted Instruction: A Book of Readings, eds. Richard C. Atkinson and H.A. Wilson (New York: Academic Press, Inc. 1969), p. 348.

ten times more effective as a means of instruction. Presently, this cannot be substantiated. It was also suggested that the costs could be reduced by increasing the number of hours per day that the equipment is in use (however, few parents would let their children attend school late at night).[3] Some use extension is possible, of course, but this would not be an effective way to cut the costs to the necessary levels. Kopstein and Seidel's proposed solution was to go to bigger systems using up to five hundred terminals as a solution to high costs.[4] This depends on an increasing technology to allow larger and, therefore, more economical systems.

Jamison, Suppes, and Butler present a case for comparing the cost effectiveness of CAI with that of more typical classroom methods.[5] They concluded that CAI was competitive with traditional methods on this basis; in this way, they developed positive evidence that CAI is a most effective teaching medium. CAI presently costs more than the conventional systems, but Stelzer noted that an examination of the alternatives to the New York system (which uses a large-scale computer) found that by using a small (ten - to twenty - user) time-share system, costs could be cut almost in half.[6]

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[3]Kopstein and Seidel, p. 349.

[4]Kopstein and Seidel, p. 358.

[5]D. Jamison, P. Suppes, and Cornelius Butler, "Estimated Costs of Computer Assisted Instruction for Compensatory Education in Urban Areas," Educational Technology, Vol. X, No. 9 (September, 1970), pp. 49-57.

[6]John Stelzer, "Computer Assisted Instruction and Vocational Education," Educational Technology, Vol. XI, No. 3 (March, 1971), pp. 43-47.

In another instance, Butler reported on the CAI system in New York City at the end of its first full year of operation.[7] He analyzed a detailed cost breakdown that spread the purchase price over a ten-year period. In this analysis, costs totaled $3.73 per student hour of instruction (this is for a large system with one computer and one hundred terminals). The $3.73 figure includes personnel and programming. It is possible that costs could be even further reduced in time.

Stelzer's research indicated that a small-scale system of four to thirty-two users could reduce costs to acceptable levels for programs preparing people for General Educational Development (GED) tests.[8] It should be noted that most articles of this type are a discussion of CAI in general; they contain little specific information on the costs or utility of any given system, either minicomputer or large scale.

A general discussion of large- versus small-scale systems is included in an article written by Max Sherman. In the final section of the article, he covers cost and convenience aspects of both large- and small-scale systems, such as the personnel, telephone, and extra EDP services which the system might perform after regular school hours or simultaneously with student instruction.[9]

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[7]Cornelius F. Butler, "CAI in New York City," Educational Technology, Vol. IX, No. 10 (October, 1969), pp. 84-87.

[8]Stelzer.

[9]Max Sherman, "Computers, Instruction and the Curriculum," Educational Technology, Vol. X, No. 5 (May, 1970), pp. 53-55.

Cost factors are discussed in the April 1969 issue of Educational Technology in which John Feldhusen and Michael Szabo examined most of the expenses involved for CAI in general, particularly at the university level. Not surprisingly, using CAI at the college level is nearly as expensive as employing traditional methods as a result of the high costs of university instruction. Their proposed solution for developing CAI systems at this level is to go to large systems of five hundred or more terminals.[10]

Few minicomputer references relate their use either to computer-assisted instruction or to computer-administered instruction. Therefore, an effort has been made to locate references showing the need to reduce costs in CAI. There is sufficient evidence to support the idea that CAI is too expensive for most schools or school districts to afford. Few administrators are willing to spend money on a method of instruction that may cost up to ten times as much as traditionally administered instruction. If, however, we accept the premise that CAI is a desirable method of instruction, and Jamison, Suppes, and Butler support this premise in their literature, then exploring the costs of lower-priced systems is justified.[11]

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[10]John F. Feldhusen and Michael Szabo, "A Review of Developments in Computer Assisted Instruction," Educational Technology, Vol. IX, No. 4 (April, 1969) pp. 47-48.

[11]Jamison, Suppes, and Butler.

CHAPTER III

METHODS AND PROCEDURES

Sources of Information

The main sources of information are published and printed articles and price lists. To better assess the hardware requirements of the various CAI systems, informal discussions were conducted with Mr. Stephen Henry and Mr. Alan Guenther, both of the University of Montana Computer Center. Mr. Henry is the operations manager; Mr. Guenther is the chief systems programmer -- the person most familiar with both the Center's minicomputer and the Digital Equipment Corporation's (DEC) line of computers.

After a careful search for cost information on different manufacturers' computers, the Digital Equipment Corporation line was found to be the logical choice for making cost and equipment comparisons. Discussions with members of the University of Montana Computer Science Department staff confirmed this choice.

The DEC line was chosen for several reasons. Detailed direct costs and some indirect costs are readily available.[1] The University currently has a DEC minicomputer in use that is quite familiar to the computer center personnel. The DEC line includes both minicomputers and

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[1]Digital Equipment Corporation, Authorized Federal Schedule Price List (Maynard, Mass., July 1, 1971 - June 30, 1972); and Digital Equipment Corporation, PDP 11/20 Price List (Maynard, Mass., August, 1, 1971).

large scale time-share machines; this eliminates any brand-to-brand differences which might have been encountered otherwise. Lastly, the prices in the DEC line seem to be near the average for the industry; these figures may be found in several sources.[2] (See table 10, page 37).

Treatment of the Data

The cost information is to be broken down in several ways to facilitate the various comparisons to be made. First, the purchase prices for all systems are to be listed and compared. Then they are to be broken down into monthly rental rates derived from a ratio of one to forty, rental rate to purchase price.[3] This ratio is common in instances where a company sells machines outright and does not rent them. Added to the calculated rental price is the monthly service costs. These service figures are to be on a monthly contract basis.

To make a more clearly comparative cost listing, systems using large-scale computers of the type currently used in many CAI installations, are included.

Not shown in tables or lists, but still important, are costs such as air conditioning, heating, and plant modification that may be needed to install a given system. Even though these factors are ever-present, their costs can only be calculated for a given installation; no general rules have been established except that minicomputers

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[2]Datapro Research Corporation, All About Minicomputers, reprinted from June 1971 Supplement to Datapro 70 (1971 Edition); Computers and Automation, Vol. 20, No. 6B (June 30, 1971), pp.27-54; and Computers and Automation, Vol. 19, No. 6B (November 30, 1970), pp. 25-52.

[3]Computers and Automation, Vol. 19, No. 6B (November 30, 1970), p.26.

usually require less plant modification than do the large-scale systems.

For the purpose of cost comparison, two hypothetical systems were investigated -- one with sixty terminals, one with fifteen terminals. For both the sixty-terminal system and the fifteen-terminal system there are three possible configurations. (1) The use of one minicomputer for each student, thus allowing greater flexibility in the placement of student terminals and improving the reliability of the system (i.e.: if a computer breakdown occurred, only one terminal would be disabled instead of fifteen or sixty). (2) The use of a larger minicomputer in a time-share mode with fifteen terminals. In this type of system, only one machine is needed for the fifteen-terminal system and only four computers are needed for the sixty-terminal system. The minicomputer time-sharing concept possesses the advantage of the other minicomputer systems -- one computer per student -- with the added advantage of a lower cost due to more efficient use of peripheral equipment. (3) The use of one large time-share machine to handle all fifteen or sixty terminals. This type of a system allows uses other than that of CAI. All the computing power is concentrated in one machine; therefore, scheduling and record keeping can be handled simultaneously with CAI. Terminals are often attached to a large machine by means of regular telephone lines; this adds the inconvenience of placing a call, as well as extra expense. The minicomputer systems are usually wired directly from the terminal to the computer.

The sixty station system would be suitable for a large school intending to use the computer for general instruction. Sixty

terminals could give up to twenty-four hundred student-hours of individualized instruction per week.[4] The fifteen-terminal system could be used for more specialized purposes in smaller schools or for special programs in larger schools. Fifteen terminals would limit student instruction to six hundred student-hours per week.[5]

Once the specifications for the various systems were determined, the prices were obtained from the various companies' latest available price lists and were put in tabular form to facilitate the comparisons. The monthly rental rates were calculated for all of the systems, along with overall cost per hour. The cost per hour is based on continuous usage with no idle time, and includes only the cost of hardware, not that of personnel or of software.

The first seven tables give information that enables a direct cost comparison to be made between each of the three different configurations for each system. Tables 8 (page 31) and 9 (page 33) contain the final cost comparison figures.

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[4]Based on eight hours a day, five days a week, times sixty terminals.

[5]Based on eight hours a day, five days a week, times fifteen terminals.

CHAPTER IV

FINDINGS

The specifications for the various DEC systems for CAI were formulated during several meetings with Mr. Guenther. The six systems shown, three with fifteen terminals and three with sixty, are the result of these discussions and comprise the minimum hardware specifications deemed necessary for CAI operation.

The first system, which uses one computer for each student looks promising at first glance because no connecting lines to the central computer are necessary; this makes the placement of the terminals very flexible. The basic computer (a PDP-8E minicomputer), complete with a teletype terminal, costs $4,990.00. However, without additional hardware, the PDP-8E is unsuitable for CAI use because it has only 4K (4,000 words) of core storage memory. With this small memory, lessons would have to be short. With the addition of a disk pack memory and its controller, the memory is expanded to thirty-six thousand words of memory storage, and thus becomes large enough to handle almost any CAI program. There is another major problem connected with the PDP-8E (or with any minicomputer in this price range); that is, that there is a problem in inserting the CAI program into the computer's memory. A high speed paper tape reader or another high speed input device is required to accomplish this at a practical speed,

When the costs of the disk pack and controller (total $6,000.00) and the cost of the paper tape reader ($2,400.00) are added to the cost of

the computer and terminal ($4,990.00), the cost for each student station becomes $13,390.00. A fifteen-terminal system would cost $200,850.00; a sixty-terminal system would cost $803,400.00.

The monthly maintenance for each student station averages to $115.00, making the total cost for fifteen terminals $1,725.00 per month, and the total cost for sixty users $5,500.00 per month. (See Table 1, page 19).

Table 1

System Costs and Maintenance Figures

Using One Minicomputer per Student

Component	Basic Cost	Monthly Maintenance
PDP-8E Minicomputer	$ 4,990.00	$ 70.00
DF 32D Disk and Controller	6,000.00	30.00
PR8-EB Paper Tape Reader	2,400.00	15.00
TOTALS:		
For 1 unit	$ 13,390.00	$ 115.00
For 15 units	200,850.00	1,725.00
For 60 units	803,400.00	5,500.00

Source: Authorized Federal Supply Schedule Price List. Digital Equipment Corporation, Maynard, Mass. Period: July 1, 1971, to June 30, 1972.

The second minicomputer system (see tables 2, page 22 and 3 page 23) is similar to that suggested by Jamison, Suppes, and Butler.[1] In this system, a slightly larger minicomputer (PDP 11/20-CA) is used in a time-sharing mode. With the use of additional memory disks for each machine and a high speed input device for each machine, the PDP 11/20-CA is capable of monitoring fifteen student terminals simultaneously. A single computer plus accessories comprises the fifteen-terminal system. In the sixty-terminal system, four fifteen-terminal systems are used, each of which operates independently.

The sixty-terminal system requires four PDP 11/20-CA computers at a cost of $11,450.00 each; $45,800.00 in total. For the PDP 11/20 to be capable of time-sharing, it must have an additional 24K (24,000 words) of memory; this is accomplished by adding three MM 11-EX which are 8K core storage units, to each computer. Each memory unit costs $6,000.00. This totals $18,000.00 for a fifteen-terminal system. In addition to the core storage, a disk memory is required to facilitate time-sharing. These disks and their controllers add $14,000.00 to the cost of each fifteen-terminal system. As with the PDP-8E system, a high speed reading device is necessary to insert the CAI programs into the computer memory. As with the PDP-8, this is done with a high speed paper tape reader, which adds $2,400.00 to the cost of each fifteen-terminal system. Another expense, of course, is for the terminals themselves, since only one is supplied with each computer. Fourteen more

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[1] D. Jamison, P. Suppes, and Cornelius Butler, "Estimated Costs of Computer Assisted Instruction for Compensatory Education in Urban Areas," Educational Technology, Vol. X, No. 9 (September, 1970), pp. 49-57.

must be added to complete each system. Terminals and their required controllers cost $1,600.00 each; this adds $22,400.00 to the fifteen-terminal system. Other additions to the above costs are a real time clock and a bootstrap loader; both are necessary to complete the system. This cost totals $500.00. Thus, the actual cost of buying a single fifteen-terminal system is $68,800.00. Combining four fifteen-terminal systems to provide sixty terminals costs $275,200.00 (see Table 2, page 22).

The monthly maintenance for a fifteen-terminal system is $750.00; this means a cost of $3,000.00 for a system of sixty. These charges are equally applicable to systems that are purchased or to ones that are rented on a monthly basis (Table 3, page 23).

Table 2

Minicomputer Time-Share System Purchase Costs

(60 Terminals)

Component	Unit Cost	Number Required	Total Cost
PDP 11/20-CA Minicomputer	$11,450.00	4	$ 45,800.00
MM11-EX 8K Core Storage	6,000.00	12	72,000.00
KW11-L Real Time Clock	250.00	4	1,000.00
PR11 High Speed Paper Tape Reader	2,400.00	4	9,600.00
BM792YA Bootstrap Loader	300.00	4	1,200.00
RS 11 Disk Pack	9,000.00	4	36,000.00
RF 11 Disk Controller	5,000.00	4	20,000.00
KL 11-A Teletype Control	400.00	56	22,400.00
LT33-LL Teletype	1,200.00	56	67,200.00
		TOTAL COST	$275,200.00

Source: PDP 11/20 Price List, Digital Equipment Corporation, Maynard, Mass. August 1, 1971.

Table 3

Monthly Maintenance Rates for Minicomputer Time-Share System (60 Terminals)

Component	Unit Rate	Number Required	Total Rate per Month
PDP 11/20-CA Minicomputer	$110.00	4	$ 440.00
MM11-EX 8K Core Storage	40.00	12	480.00
KW11-L Real Time Clock	3.00	4	12.00
PR11 High Speed Paper Tape Reader	15.00	4	60.00
BM792YA Bootstrap Loader	3.00	4	12.00
RS 11 Disk Pack	49.00	4	160.00
RF 11 Disk Controller	25.00	4	100.00
KL 11-A Teletype Control	6.00	56	336.00
LT33-LL Teletype	25.00	56	1,400.00
		TOTAL MONTHLY CHARGES	$3,00.00

Source: PDP 11/20 Price List, Digital Equipment Corporation, Maynard, Mass. August 1, 1971.

The last system presented uses one large computer to handle all the terminals, whether fifteen or sixty. This system can handle many other jobs coincidentally because of its concentrated power. Representative of this system is the PDP-10F96 computer, a large-scale machine with ninety-six thousand words of memory. These computers cost $440,000.00 each. Even a machine of this magnitude, however, needs extra memory disks in order to handle time-sharing. For sixty terminals, an RM10B Drum and an RC10 Drum Controller are used; this brings the system to capacity at a total cost of $69,000.00. A positive feature of the PDP-10F96 line is that a high speed reader comes with the computer; this eliminates the added cost of that item. A data channel is necessary to handle all the communication lines coming in from the various terminals. This adds $14,000.00 to the purchase price. No terminals come as standard equipment with this computer. It is necessary to purchase either fifteen or sixty terminals at a cost of $1,200.00 each. This would be $72,000.00 for sixty terminals. A special teletype controller that can handle eight terminals is used for the PDP-10 computers. These are $5,500.00 each, a total of $44,000.00 for the eight controllers required for sixty terminals. The total purchase price of a system designed to handle sixty terminals is $639,000.00 (see table 4, page 25).

The total monthly maintenance charge for the sixty-terminal system is $3,111.00 (table 5, page 26).

Table 4

Large-Scale System Purchase Costs

(60 Terminals)

Component	Unit Cost	Number Required	Total Cost
PDP-10F96 Computer	$440,000.00	1	$440,000.00
RM 10B Drum	50,000.00	1	50,000.00
RC 10 Drum Controller	19,000.00	1	19,000.00
DF 10 Data Channel	14,000.00	1	14,000.00
DC 10-B Teletype Controller	5,500.00	8	44,000.00
LT33-L Teletype	1,200.00	60	72,000.00
		TOTAL PURCHASE PRICE	$639,000.00

Source: Authorized Federal Supply Schedule Price List, Digital Equipment Corporation, Maynard, Massachusetts, period July 1, 1971 to June 30, 1972.

Table 5

Monthly Maintenance Rates for Large-Scale System

(60 Terminals)

Component	Unit Rate	Number Required	Total Rate per Month
PDP-10F96 Computer	$1,248.00	1	$1,248.00
RM 10B Drum	30.00	1	30.00
RC 10 Drum Controller	145.00	1	145.00
DF 10 Data Channel	60.00	1	60.00
DC 10-B Teletype Controller	16.00	8	128.00
LT33-LL Teletype	25.00	60	1,500.00
		TOTAL MONTHLY CHARGES	$3,111.00

Source: Authorized Federal Supply Schedule Price List, Digital Equipment Corporation, Maynard, Massachusetts, period July 1, 1971 to June 30, 1972.

The fifteen-terminal large-scale system (see Table 6, page 28) varies little from the sixty-terminal system. The PDP-10F96 is still used; a RP02 disk and RP 10 controller do replace the drum used on the sixty-terminal system, however, the disk and controller cost $53,000.00 -- a saving of $16,000.00 over the drum system. The other major difference is that there are fifteen terminals instead of sixty, requiring two controllers instead of eight. The fifteen terminals and the two controllers cost $29,000.00. The total purchase price for the large-scale fifteen-terminal system is $536,000.00, only $103,000.00 less than the sixty-terminal system.

The monthly maintenance charge for the large-scale fifteen-terminal system is $1,910.00 (Table 7, page 29).

Table 6

Large-Scale System Purchase Costs

(15 Terminals)

Component	Unit Cost	Number Required	Total Cost
PDP-10F96 Computer	$440,000.00	1	$440,000.00
RP 10 Disk Control	27,000.00	1	27,000.00
RP 02 Disk Pack	26,000.00	1	26,000.00
DF 10 Data Channel	14,000.00	1	14,000.00
DC10-B Teletype Controller	5,500.00	2	11,000.00
LT33-LL Teletype	1,200.00	15	18,000.00
		TOTAL COST	$536,000.00

Source: Authorized Federal Supply Schedule Price List, Digital Equipment Corporation, Maynard, Massachusetts, period July 1, 1971 to June 30, 1972.

Table 7

Monthly Maintenance Rates for Large-Scale System

(15 Terminals)

Component	Unit Rate	Number Required	Total Rate per Month
PDP-10F96 Computer	$1,248.00	1	$1,248.00
RP 10 Disk Control	70.00	1	70.00
RP 02 Disk Pack	125.00	1	125.00
DF 10 Data Channel	60.00	1	60.00
DC10-B Teletype Controller	16.00	2	32.00
LT33-LL Teletype	25.00	15	375.00
		TOTAL MONTHLY RATE	$1,910.00

Source: Authorized Federal Supply Schedule Price List, Digital Equipment Corporation, Maynard, Massachusetts, period July 1, 1971 to June 30, 1972.

In comparing the various fifteen-terminal systems, it is necessary to observe purchase prices, maintenance costs and rental rates (Table 8, page 31). If purchase costs are to be examined, then the total cost of each system must be considered. On this basis, the PDP-11 minicomputer time-sharing system, costing $68,750.00 is the most economical (see Table 2, page 22). The system using one computer per student costs almost three times as much at $200,850.00 (see Table 1, page 19) and the large-scale system costs more than twice again as much at $536,000.00 (see Table 6, page 28). Regardless of how a system is acquired, the cost of maintenance must be considered; again, the minicomputer time-sharing system costs the least at $750.00 (one-fourth the total monthly charges for the sixty-user system, Table 3, page 23) with the other systems costing $1,725.00 (Table 1, page 19) and $1,910.00 (Table 7, page 29) respectively, for maintenance. These are 15-unit costs.

If rental is to be considered, then it is convenient to add the cost of the rent to maintenance. In this case, the small time-sharing system again costs far less than the other two systems. The PDP-11 system rents for $2,468.75 per month as compared with $6,746.25 rent for the PDP-8 system, and $15,310.00 for the large-scale PDP-10 system (Table 8, page 31).

It is also meaningful to examine the cost per student-hour of instruction. The minicomputer time-sharing system costs only $0.94 per student-hour for hardware use, as compared with $2.42 per student-hour for the indiviaul minicomputer system and $6.08 for the large-scale system (Table 8, page 31).[2]

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[2]Based on 8 hours per terminal per day and on 21 days per month, which totals 2,520 hours per month, assuming continuous usage.

Table 8

Minicomputer Systems versus Large-Scale System

(15 Terminals)

Item	(PDP-8) Individual System	(PDP-11) Time-Share Minicomputer System[3]	(PDP-10) Large-Scale System
Initial Cost	$200,850.00	$68,750.00	$536,000.00
Cost per Terminal	13,390.00	4,583.33	35,733.00
Monthly Rent[4]	5,021.25	1,718.75	13,400.00
Monthly Maintenance	1,725.00	750.00	1,910.00
TOTAL MONTHLY COSTS	6,746.25	2,468.75	15,310.00
Cost per Student-Hour of Instruction[5]	2.42	0.94	6.08

[3]Based on one-fourth the total of the sixty-terminal system.

[4]Based on a factor of forty from total purchase price.

[5]Based on 8 hours per terminal per day, for 21 days per month, totalling 2,520 hours per month, assuming 100% usage.

When comparing the sixty-terminal systems, the same factors must be considered as in comparing the fifteen-terminal systems. In the sixty-terminal systems, the PDP-11 system is the least expensive in all areas: its total purchase price is $275,000.00 and its monthly maintenance is $3,000.00. Compare this with $803,400.00 and $5,500.00 (for purchase price and maintenance) for the PDP-8 system using one computer per student; and $639,000.00 and $3,111.00 respectively for the PDP-10 large-scale system. It should be noted that the use of sixty terminals brings the cost of the large-scale system down near the cost of the individual system. (See Table 9, page 33).

This is much the same for rental figures. The total monthly rental costs for the PDP-11 system would be $9,875.00 as compared with $25,585.00 for the PDP-8 system, and $19,086.00 for the PDP-10. The cost per student hour is $0.94, $2.42 and $1.81 respectively, for the three types of systems PDP-11, PDP-8, and PDP 10.

Table 9

Minicomputer System versus Large-Scale System

(60 Terminals)

Item	Individual Minicomputer System	Time-Share Minicomputer System	Large-Scale System
Initial Cost	$803,400.00	$275,000.00	$639,000.00
Cost per Terminal	13,390.00	4,583.33	10,500.00
Monthly Rent[6]	20,085.00	6,875.00	15,975.00
Monthly Maintenance	5,500.00	3,000.00	3,111.00
TOTAL MONTHLY COSTS	25,585.00	9,875.00	19,086.00
Cost per Student-Hour of Instruction[7]	2.42	0.94	1.81

[6]One-fourtieth of the total cost equals the monthly rental rate.

[7]Based on 8 hours per day per terminal, 21 days per month, totalling 10,560 hours per month, assuming 100% usage.

Perhaps, a clearer picture of the overall costs can be seen in Figure 1, (page 35). From this graph it may be seen that for the minicomputer systems, costs rise in direct proportion to the number of terminals. However, with the larger system increases in the number of terminals do not bring an equal rise in price. If this concept is extended, it is plain to see that at some point it will be more economical to utilize one large computer than a number of small ones. Current technology does not allow this; however, it is likely that in the near future, a system that is used in a whole school district could be the most economical on a cost per terminal basis. This idea is supported by Feldhusen and Szabo in an article on developments in CAI.[8] The point remains that at the present time it is more economical to use a system of time-share minicomputers.

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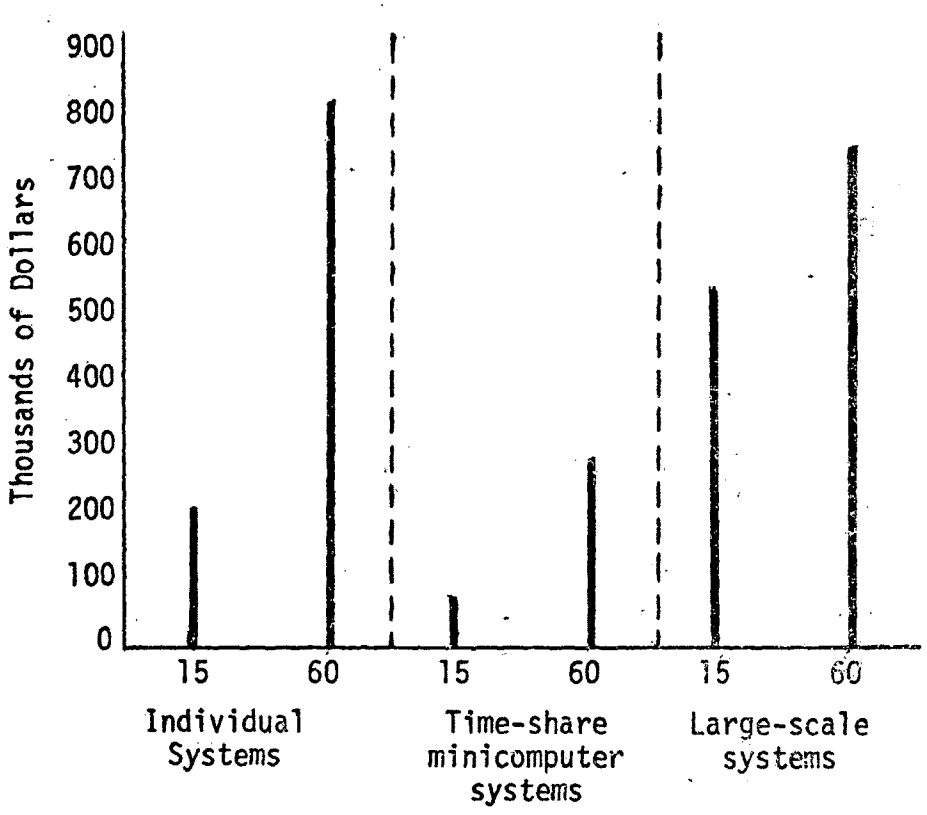
[8]John F. Feldhusen and Michael Szabo, "A Review of Developments in Computer Assisted Instruction," Educational Technology, Vol. IX, No. 4 (April, 1969). pp. 47-48.

Figure 1

Total Purchase Prices For All Systems[9]



[9]For greater detail see Tables 8 and 9, pages 31 and 33.

Some minicomputers that are suitable for CAI use are shown in Table 10, page 37. All the manufacturers listed have had at least three hundred units delivered; however, there are many manufacturers other than those shown and there may be more models in a given line than those shown. The models listed were chosen because they all had similar specifications and all were suitable for CAI, and are in general use in many different areas. All models in the table have 8K words of memory.

Costs for the peripheral equipment, teletypes, etc., may vary among different manufacturers and accessory companies; thus, no cost analysis has been included for it.

It can be seen from this table that the PDP-11 is very near the average, in CPU cost, when compared to other comparable computers.

Table 10

Cost of Minicomputer[10] CPUs from Several Different Manufacturers

Manufacturer	Model	Approximate Unit Cost
Atron	501 Datamanager	$8,000.00
Data General	Nova	12,850.00
Digital Equipment Corp.	PDP-8E	9,490.00
Digital Equipment Corp.	PDP-11/20	14,300.00
Hewlett-Packard	2114B	12,500.00
Hewlett-Packard	2116C	16,000.00
Honeywell	316	13,600.00
Interdata	Model 4	13,300.00
Varian	620/i	16,500.00

Source: All About Minicomputers, reprinted from the June 1971 Supplement to Datapro 70, copyright 1971, Datapro Research Corporation.

[10]All the Models shown have an 8K memory and have had at least three hundred units delivered.

CHAPTER V

SUMMARY

The purpose of this study was to investigate the probable advantages of minicomputer use as a means of reducing the high cost of computer-assisted instruction, assuming software and machine operation personnel costs would be similar for any type of hardware.

The first step was to search for some source of accurate pricing and cost information, but only one manufacturer had made detailed price information available.[1] A review of the journals giving general cost data indicated that the hardware costs for the DEC line of computers was approximately on an average for the industry. Furthermore, this line was one of the few that included both minicomputer and large-scale systems; this aided in eliminating brand variances.

Some discussion was necessary with University of Montana Computer Center staff to outline the hardware requirements for each system. Once the components were identified each was priced, and all of the data were put in tabular form to facilitate comparison. Also included in the tables were the calculated figures for monthly rent (gathered elsewhere, as the DEC company only sells machines), and the figures for the hardware cost per student hour of instruction. Other

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[1]Digital Equipment Corporation, Authorized Federal Schedule Price List (Maynard, Mass.: July 1, 1971 - June 30, 1972); and Digital Equipment Corporation, PDP 11/20 Price List (Maynard, Mass.: August 1, 1971).

costs were designated as unknown factors and were omitted. Thus, a general cost picture for the use of minicomputers for CAI was determined.

Implications

In the future, the trend will probably be toward the utilization of small time-share systems, using minicomputers; these systems should eventually dominate the field of computer-assisted instruction, assuming that current price trends are not greatly altered. This analysis of the various facets of CAI has shown the minicomputer system to be preferred to the large-scale systems. The time-share minicomputer system is capable of performing other computing jobs required by a school, at a somewhat slower speed than is done by the large-scale machines. Attendance control, grading, scheduling and general bookkeeping could be handled after hours as well by the small time-share system as by the large-scale systems. The individual minicomputer system, however, would probably not be able to perform any other jobs simultaneously with CAI. There are favorable points regarding the upkeep of the minicomputer system. The smaller systems do not generally require the regulated temperature and humidity controls needed for the large systems. The machine operation personnel requirements are similar for both systems; however, building modifications to house the computer system are not needed for minicomputers. For example, such things as false floors to hide complex wiring are not usually necessary with the smaller systems.

Computer-assisted instruction could go the way of educational television -- a great promise, at first, with fast fading development; hopefully this will not happen. There is a need for individualized

instruction; CAI is an innovative means of giving every student the opportunity to learn at his own pace.

Conclusions

The necessity for additional storage and a high speed input device are the disabling factors in considering the one minicomputer per student-system for general CAI use. The added equipment more than doubles the cost per terminal for a minicomputer system.[2] Until the cost of the extra equipment is reduced, or until the individual machine's capacity is increased without a basic cost increase, using one minicomputer per student will not be economically feasible.

Using larger, time-share minicomputers is the preferred approach. These small machines are inexpensive by computer standards and they have the advantage of a time-sharing capacity, on a limited basis. By using four such computers, monitoring fifteen terminals each, the cost is about one-half of that which would be encountered in a comparable large-scale system. The smaller time-share system has the added advantage of having many CAI programs currently available to them. However, this approach is still prohibitively expensive.

Large-scale machines dominate the CAI field because this instruction is, in most cases, a secondary function of the computer system. Large universities and other institutions in which CAI is now receiving extensive attention, are using computers for research and general business purposes, as well as CAI. Furthermore, CAI, although

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[2]Table 8, page 31, and Table 9, page 33.

operational, is in the research stage, for the most part.

Future Trends

If the current decreasing cost trends continue (caused by technical advances and competition) in the computer field, CAI should become inexpensive enough for most schools or school systems to utilize.

CAI may follow two main paths in the future. The first concerns the use of computers as a classroom teaching aid. Students may soon write their own programs in order to solve the various problems related to their course work. This aspect of computer-assisted instruction could continue to grow as the use of computers in other areas of education and science continues to grow. Due to decreasing costs and high versatility, minicomputers should play an ever-increasing role in CAI.

The second type of CAI which should develop further will involve the use of computers to administer instruction. Man-machine interaction is a dynamic way to individualize instruction. This mode of CAI has great potential, but it may not experience as wide-spread an initial usage as will the other form of CAI. The possibility does exist that most people will see computer-administered instruction as many people view educational TV -- a gimmick. If this is true, then this aspect of CAI will never gain wide-spread, general use. Hopefully this will not be the case.

In conclusion, CAI may not ever reach its full potential; however, the use of computers as a classroom teaching aid in which students do their own programming will undoubtedly be increased, even if the use of computers to administer instruction is not utilized to the fullest possible potential.

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C. REPRINT

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D. PRICE LISTS

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