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ABSTRACT

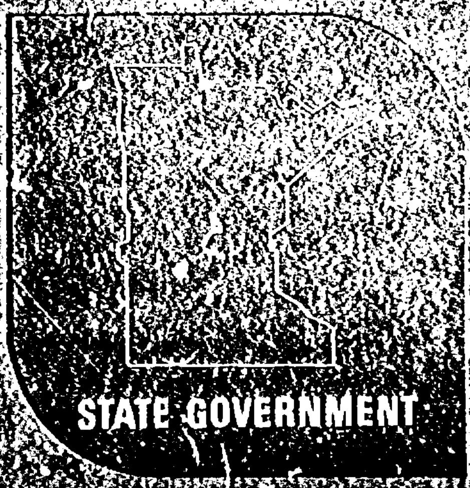
Section 1 of this report argues the necessity for computers in higher education today, in terms of the objectives of the five systems of post-secondary education in Minnesota. Section 2 covers the present status of computer facilities and activities in Minnesota higher education. Section 3 contains a quantitative analysis of the needs for computing capacity over the next ten years. Section 4 converts this needed capacity into general computer hardware configurations and geographical deployments, and estimates the total costs involved. Section 5, the final section, presents 30 specific recommendations for providing Minnesota higher education with the computing capacity it needs over the next five- and ten-year periods, complete with estimated budget schedules and commentary on the relationship of the projected costs to national standards and other costs of higher education. It is suggested that the reader who lacks the time to digest the entire report will be exposed to most of the important points and recommendations contained in it by reading Sections 1 and 5. This report is included as Part IV of LI 002 385, "Information Systems in the State of Minnesota 1970-1980". Part II, the summary of the entire study is also available as LI 002 386. (Author/NH)

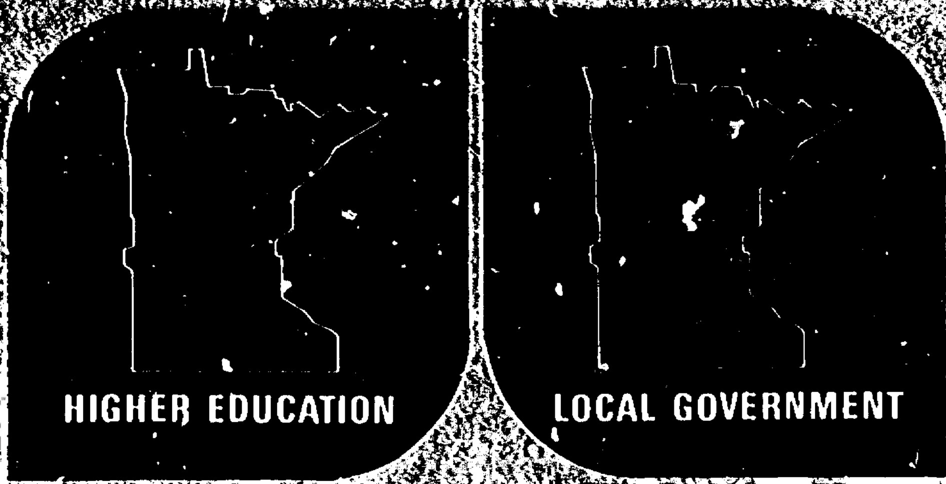
ED 045168

COMPUTERS AND INFORMATION SYSTEMS IN HIGHER EDUCATION

PART OF

INFORMATION SYSTEMS IN THE STATE OF MINNESOTA 1970-1980





ERRATA to the Report, Computers and Information Systems in Higher Education, Part IV of Information Systems in the State of Minnesota, 1970-1980.

Peter G. Roll
November 24, 1970

Page 4-52: The second and first paragraphs from the bottom of the left hand column (beginning "Computer installations serving ...." and "Regional or statewide ...") should be numbered 3. and 4. respectively.

Page 4-63/4-64: The line on this figure labeled DULUTH REGIONAL CENTER should not be blank, but should contain the following facilities expansions as implied by Tables 5.2 through 5.5:

1972: Computer core memory expansion
1973: Computer core memory expansion
1976: Substantial expansion or replacement of computer.

Page 4-49: Title for Table 4.5 should read "Summary of Monthly Lease Costs Associated with Each of the Deployment Configurations Analyzed for 1975 (1970 Dollars)"

Appendix H.9, Title page: The title of this Appendix should read, ALTERNATIVE DEPLOYMENT CONFIGURATIONS FOR COMPUTERS IN MINNESOTA HIGHER EDUCATION IN 1975.

Page 4-66, Table 5.1: Add to footnote (m): The equivalent annual lease and recommended support budgets for the Mankato Regional Center are $324,000 and $300,000, respectively.

Page 4-67, Table 5.2: The table title should read, "Proposed Funding Schedule for Computing Equipment to be Added During 1971-75."

Page 4-68, Table 5.3: A footnote should be added to this table as follows: The total equivalent annual lease costs for each of the years 1971-1975, including equipment acquired prior to 1971 as well as the added facilities, may be obtained by adding the figures in the third column of Table 5.1 to the costs in this table. Note that, according to Footnote (m) in Table 5.1, the figure $324,000 must be used for the equivalent annual lease cost of the Mankato computer, rather than the $200,000 estimated for the partial year 1970-71.

ERRATA (Continued)

Pages 4-69 and 4-70, Tables 5.4 and 5.5: A heavy line should be drawn below the entry AREA VOCATIONAL-TECHNICAL SCHOOLS, to separate it from the unrelated items just below.

Page 4-72 and Page 2-22 in the Summary: To maintain consistency with the added footnote to Table 5.3, $124,000 should be added to the facilities and total costs in the small table for the years 1971-75. With this addition and correction of a typographical error in the 1971-72 Support cost, the table will read as follows:

ANNUAL COST DATA

Academic Year	Facilities	Support	Total
1970-71	2,360,000	1,864,000	4,224,000
1971-72	3,073,000	2,684,000	5,757,000
1972-73	3,587,000	3,164,000	6,751,000
1973-74	4,121,000	3,754,000	7,875,000
1974-75	4,796,000	4,338,000	9,134,000

PART IV
HIGHER EDUCATION

PREFACE

The length and somewhat tedious detail of this study of computers in Minnesota higher education is at least as apparent to its authors as it will be to its readers. Section 1 of the report argues the necessity of computers in higher education today, in terms of the objectives of the five systems of post-secondary education in Minnesota. The final section, Section 5, presents 30 specific recommendations for providing Minnesota higher education with the computing capacity it needs over the next five- and ten-year periods, complete with estimated budget schedules and commentary on the relationship of the projected costs to national standards and other costs of higher education. By reading these two sections, the reader who lacks time to digest the entire report will be exposed to most of the important points and recommendations contained in it. In between, Section 2 covers the present status of computer facilities and activities in Minnesota higher education; Section 3 contains a quantitative analysis of the needs for computing capacity over the next ten years; and Section 4 converts this needed capacity into general computer hardware configurations and geographical deployments, and estimates the total costs involved. Those readers who are unfamiliar with computer systems using remote terminals may find it especially helpful to read Section 4.3, and perhaps Sections 4.1 and 4,2, to learn just what is involved in them.

Frequent reference is made in this part of the report to ten Appendices, labeled H.1 through H.10. These appendices contain information on the conduct of the study, papers written on special topics of importance to computer applications in higher education but which could not be covered adequately during the study, and details and tables of results from the analyses in Sections 2, 3, and 4 of the main report. These appendices are not bound in copies of the general report which also addresses information systems in state and local government. The interested reader may obtain a copy of the higher education report bound together with its Appendices from the Higher Education Coordinating Commission.

Finally, we should like to emphasize that, although the recommendations and development schedules in Section 5 are in a sense a "Master Plan" for computing in higher education in Minnesota, they cannot and must not be interpreted as specific, rigid implementation plans or schedules, but rather as guidelines for the development of specific implementation plans and for the evaluation of those plans. It is properly the function of the various systems and institutions of higher education to develop and propose specific, detailed implementation plans, and the function of the coordinating organizations and the State Legislature to evaluate and fund the plans. If this report is acceptable, it may provide a useful basis for planning and evaluation, but the hard work of detailed planning and implementation must be left to higher education itself.

ACKNOWLEDGMENTS

Whatever acceptance this report receives will be a result in part of numerous consultations with faculty members and administrators in many institutions and all of the systems of post-secondary education in Minnesota, as well as with several representatives of the computer industry. Most of these individuals are listed in Appendix H.1. The authors are most grateful to them for their generosity and hospitality in meeting with us, and apologize for any names which have been omitted inadvertently, misspelled, or incorrectly identified. Professor Russell W. Burris and Dr. Frank Verbrugge of the University of Minnesota, Dr. John E. Haugo of the State College Board, Richard Peterson of the State Department of Education, Banning Hanscomb, Donald Wujcik and Dr. Howard Bergstrom of the State Junior College Board, and Richard Paulson of Macalester College were especially helpful to us. Periodic reviews and encouragement from the Computer Advisory Committee of the Higher Education Coordinating Commission were important in shaping the report, as were information, advice, and technical support received from the staff of the Coordinating Commission, and especially from its Executive Director, Richard C. Hawk.

Minneapolis, Minnesota
September 1970

Peter G. Roll
Peter C. Patton

PART IV
HIGHER EDUCATION

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1. INTRODUCTION

During the past two decades, the development of electronic computing and data processing machines has had a profound impact on all aspects of American society – an impact unmatched by other technological developments in our history. Starting in the late 1940's as the esoteric research tool of a few scientists and mathematicians, computers have invaded almost every part of our economy and society. Science and engineering were the first areas; then came applications to fiscal operations of business and other large organizations, and to the operations of government. Computers have become the tools of the artist and musician, the literary scholar, the printer (automatic typesetting), the surveyor, the carpenter (job estimating), and even the taxpayer, who today can avail himself of several services which make use of remote, time-shared computer terminals to assist in filling out IRS Form 1040. Rather than merely automating traditional procedures formerly carried out by large numbers of clerks or engineers, electronic computing and data processing machinery has begun to change profoundly the systems and organizations which use them – business, industry, government, hospitals, education. To quote from a report of the President's Science Advisory Committee in 1967[1],

> After growing wildly for years, the field of computing now appears to be approaching its infancy.

A technology with this social impact must, and has, invaded higher education. The computer has evolved in higher education from an object and tool of research to both an object of instruction and a tool of instruction. This evolution has proceeded in a relatively uncoordinated way, in Minnesota as well as elsewhere in the nation. The evolution has by now progressed to the point at which the computer is beginning to have significant effects on the methods, content, and organization of higher education. It is the need for coordination of these efforts, and the costs of providing the computer and data processing facilities which they imply, which led to the present study.

This report will endeavor to provide answers to the following questions:

- Why are computers needed in higher education?
- How much computer capacity is needed to serve higher education in Minnesota?
- How much will this computer capacity cost?
- How can computer applications in Minnesota higher education be coordinated and organized effectively to provide the maximum benefits to students and society, at the least cost to the taxpayer?

As the location of a significant fraction of the American computer and computer-related electronics industry, the State of Minnesota has a special stake in the health of that industry, and in the vigor of programs in higher education which use or relate to the products of the computer industry. However, it will be the *objectives* of higher education in the various systems and institutions which form the basis for the analysis directed at the above questions, and for the recommendations at the end of this report.

THE OBJECTIVES OF POST-SECONDARY EDUCATION

Higher education in the United States traditionally has had three objectives:

- Instruction
- Research
- Public Service

Some kinds of institutions divide their efforts among all three missions, and others specialize in just one or two of them. To understand the place of computers in meeting these objectives today, it is important to have a clear understanding of what the objectives really mean, and which of the objectives apply to each of the five systems of higher education in Minnesota:

- The University of Minnesota
- The State Colleges
- The State Junior Colleges
- The Area Vocational-Technical Schools
- The Private Colleges

Although referred to in this report as "systems", the last two listed are not coherent systems in the same sense as the first three. The Area Vocational-Technical Schools are creatures of local government — Independent or Intermediate School Districts — coordinated by the State Board of Vocational Education and the State Department of Education. As such, they are represented indirectly in the other two major parts of this study, covering state agencies and local government. Sixteen of the private colleges are members of the Minnesota Private College Council, through which they are represented on the Higher Education Coordinating Commission. They do not form a "system" in any but the loosest sense of that word.

Each of the three objectives of higher education is now addressed in turn.

Instruction

Instruction of students is the primary reason for the existence of post-secondary institutions in this country, and for *some* of the institutions, it is their only objective. But there are three kinds of instruction which are distributed among the five systems —

- **General education of students** to understand and appreciate themselves, other people, and the physical, social, and intellectual world in which they live. This kind of instruction is an important function of the university, the state colleges, the private colleges, and transfer and some non-transfer programs in the junior colleges. In the classical sense, this objective is the heart of a liberal arts education. However, it does not play a major role in the Area Vocational-Technical Schools.

- **Vocational training.** This kind of instruction is the exclusive objective of the Vocational Schools, the vocational programs in the junior colleges, and certain vocational programs in the colleges and university. It is aimed at preparing students to enter a job and begin earning their pay within a few days after they start, on the basis of the specific training they have received. The jobs for which vocational training is provided are well defined, and it is relatively easy to establish a successful training program and determine whether or not a student has completed it satisfactorily.

- Professional education. The objective of professional training is not to produce graduates who can step into a job and begin producing immediately (although this may happen), but to prepare a person with a basic understanding of his field, the methods, techniques and tools used in it, and the discipline necessary to learn what is needed to do a job and to direct and manage others in getting it done. A person with professional training at the undergraduate or graduate level may be unable to perform many tasks as well as the graduate of a non-degree vocational program. But it is from this group that most of the managers and executives come, and the people whose work leads to new kinds of jobs for others, and new ways of doing old jobs. Most students in a liberal arts curriculum today acquire in addition a considerable amount of training relevant to some vocation or profession. Professional and pre-professional training is the responsibility of the state and private colleges and the university. Most of the advanced graduate education, and professional training in areas such as law, engineering, medicine, and other health sciences, is concentrated on the University of Minnesota's Twin Cities campus.

To maintain a viable system of post-secondary education meeting the needs of the state for trained manpower, an informed and articulate citizenry, and a satisfying life, Minnesota must support all three kinds of instruction. The results and payoffs of vocational and professional education are easiest to recognize, but the general level of understanding and sensitivity of the people, enhanced more by general education, may be as important to the welfare of our society in the long run.

Research

Research may be defined as the expansion of knowledge and the development of techniques, methods and devices for solving problems related to the natural world and to man and his institutions. It is on research that the progress of society depends. The principal resource of the State of Minnesota for research is the University of Minnesota. Within higher education, the state colleges and some of the stronger private colleges also have a mission which includes research, though to a lesser extent than the university. The junior colleges and area vocational-technical schools do not serve as research institutions, except in the broad sense applicable to all institutions, whether they are in education or outside, public or private: all institutions must carry out research on their own operations, to determine whether they are meeting their goals and how to increase their effectiveness and efficiency.

Much research is of value to the state and the nation in terms of its results and applications; this is a public service of higher education. But research is a *necessity* for institutions whose mission includes graduate and post-graduate professional education. The basic understanding, the ability to use the tools and methods, and most especially the self-discipline required to learn and to generate new knowledge when it is needed — these attributes are imparted to graduate and post-graduate professional students through their participation in research. Whether these students remain in research when they leave the university or pursue their field as practitioners in some other way, it is the research-generated self-discipline and self-motivation for continual learning which characterizes them as professionals, and in which the value of their education resides.

Public Service

In a broad sense, education and research are a service to society. In addition, however, institutions of higher education in the United States have traditionally provided more direct services to the public as part of their mission. This began with accurate time-keeping service to the local community by the college astronomer (before the days of widespread telegraphic communications and railroad time zones), and agricultural extension services through the land-grant colleges. Today public services are provided by colleges and universities not only to agriculture, but to businesses, schools and school districts, the health care industry, governmental agencies, the housewife, urban renewal projects — almost all segments of society. These services most often grow out of the other two functions of higher education. Instruction has led to evening and adult education classes, and large Extension and Continuing Education Divisions within various institutions. And many of the results and methods of research, particularly at the University of Minnesota, have been developed by faculty members, working in cooperation with outside groups, for application to some of the problems of a segment of society or of the state as a whole. If higher education were not performing these services, other institutions would have to be created to provide them.

Institutional Support of the Objectives of Higher Education

Just as have most other institutions of our society, higher education has grown large, complicated, and expensive. The organizational structures required to support college and university faculty in carrying out their three missions have become more conspicuous, more important, and also more costly. Two support services which directly affect and are necessary for the primary instructional function of higher education are:

- Student services — financial aid, assistance in obtaining living accommodations and meals, extra-curricular activities, etc.
- Learning resources — libraries, audio-visual media, television, laboratory equipment, and even the computer itself. All of educational technology and applied learning psychology would fall in this category.

These two activities draw upon the results of relevant research, and may carry out research and development work where it is needed to improve their support services. The results of this kind of development effort, as well as many of the resources used in higher education, are also available as a service to the public. The University of Minnesota Libraries, for instance, are a resource available to the people of the State.

Supporting and managing the operations of each institution and system of higher education is an administration which, through its respective governing board, is legally responsible to the public for the operation of the institution or system, and for the successful accomplishment of its missions. Administration must carry out the research and develop the information and fiscal systems necessary to effective and efficient management of the educational enterprise.

Figure 1.1 may be useful in illustrating the relationships between the three objectives of higher education, which are always uppermost, and the supporting activities required to achieve them effectively and efficiently.

THE ROLE OF THE COMPUTER IN MEETING THE OBJECTIVES OF HIGHER EDUCATION

Having defined the goals of higher education, it is necessary now to define the functional areas which need computing services or facilities, and then to justify the needs in terms of the goals of higher education. For ease of discussion, several different functional areas have been defined and will be discussed in turn.

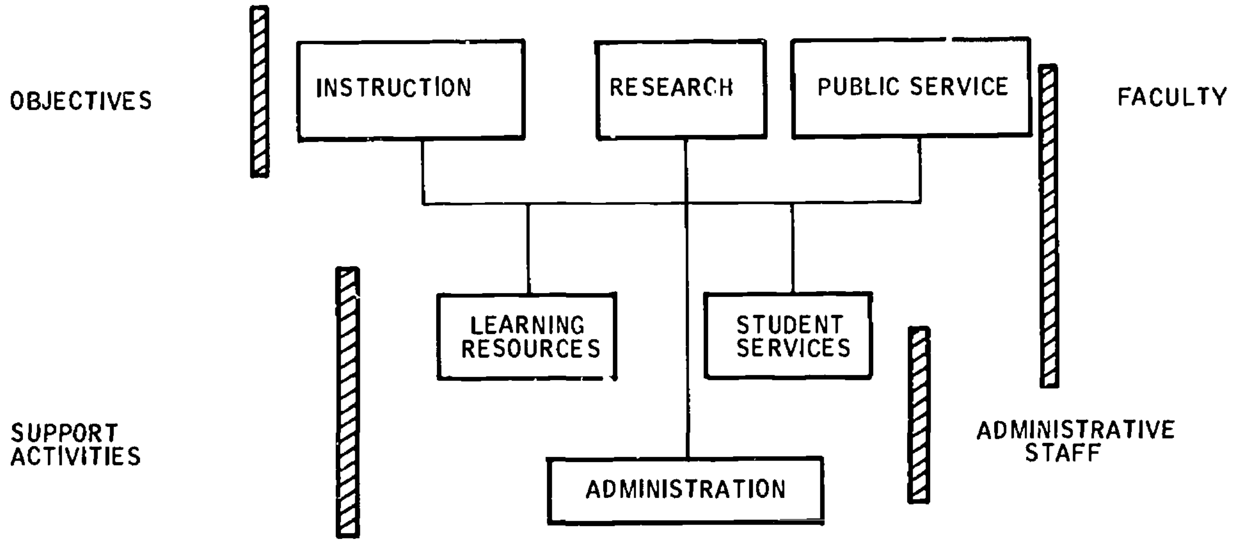


Figure 1.1. An Organizational Structure Supporting the Objectives of an Institution of Higher Education (Suggested by Dr. R. W. Brady, Ohio State University)

Administrative Data Processing

Student records, personnel files and accounts, financial records and transactions, property and space inventories, and curriculum and scheduling represent most of the administrative and student service activities in a college or university. These are tasks which lend themselves to electronic data processing, just as have the administrative data processing requirements of business, government agencies, and other large organizations. There is no essential difference between administrative data processing in institutions of higher education and in businesses or other organizations of comparable size and complexity. For this reason, the benefits of electronic data processing in higher education are similar to those which have induced many large businesses and industries to automate their administrative activities; namely, increased effectiveness in the form of better and quicker service, and increased efficiency in terms of decreased costs or costs which do not rise as fast as they would otherwise. The real benefits to be gained from administrative applications of computers are the development of effective college management information systems to improve the quality of the administrative support to students and faculty; and program planning and budgeting systems, so that it will be possible to determine true costs of programs, and to assign institutional priorities on a more rational basis using this information. Just as has been the experience in business, applications of computers will force a complete review and revision of administrative objectives, organizations and procedures, providing the institutions themselves, their governing boards, the Legislature, and the people of the State with much more adequate information on which to base decisions concerning the wise allocation of the state's resources.

Educational Computing

This is the computer application most closely related to the primary mission of higher education — instruction. But within this category, there are several kinds of computer applications which are quite different, and require some elaboration.

- **Instructional Computing** will be defined as the use of generally-accessible computers by students in all courses requiring computing, and by graduate students for their thesis work; that is, computing which is directly related to the student's learning activities and which is normally carried out on large or small general-purpose computing facilities. Except for courses in programming, the computer is used as a tool for learning (or a "learning resource"), rather than an object of instruction.

  The value of the computer as a problem-solving tool is readily apparent for students in such quantitative areas as engineering, science, accounting, and statistical analysis in the social and biological sciences. It may be less obvious, however, that computers have many instructional uses other than problem solving in academic areas ranging from engineering to the fine arts. Programs are in use which permit students to interact with a computer simulation of a bridge or building structure, an atom, a business operation, the political system of a city during an election, or a hospital patient. Using such simulation programs, students can acquire experience in making decisions and investigating the consequences of those decisions. The computer is being used successfully to analyze the expository writing of students in journalism courses at the University of Michigan. It is making possible student experience with using and interpreting information from large social data bases, such as the census data. And it has become an important medium for students in art and music at several colleges. These and many other instructional applications are described in the Proceedings of a Conference on Computers in the Undergraduate Curricula, held in June 1970 at the University of Iowa[2].

- **Computer Training** includes courses and programs in which the computer is an *object* of instruction rather than a tool. For instance, students in data processing and programming courses at area vocational-technical schools need hands-on use of either a computer or a remote-job-entry terminal. This is the environment in which they will be required to function when they get a job. Many vocational school graduates, in fact, begin their careers as computer operators, for which training in operating a *specific* computer system is not so important, but general familiarity with and experience in handling some kind of computer or terminal equipment is most important. For those students who have regular access only to a terminal, it is important that, sometime during their training, they visit a computer site for a few days of observation and hands-on experience in how a computer system functions — preferably one that handles remote as well as local processing. (These same remarks apply to the one junior college data processing program, at Lakewood State Junior College.)

There are also programs for computer maintenance technicians in operation or beginning at two of the area schools — Mankato and St. Cloud. Such programs require substantial access to computer hardware which can be taken apart and reassembled. Therefore, it simply cannot be used to provide computer service. The two schools with these programs have two of the largest computers in the state — a UNIVAC Athena and an RCA 501, respectively. Fortunately, these have been obtained as surplus at virtually no cost to the Minnesota taxpayer, so that these programs can operate on a reasonable cost basis.

The programs of the Computer, Information, and Control Science Department at the University of Minnesota, although aimed at a much different kind and level of student, are in certain respects similar to those in the area vocational schools. The graduate and perhaps advanced undergraduate training and research functions of this department, now in its second year of operation, require access to software and hardware systems with which the students can experiment. It is not feasible to carry out this kind of training on a computer system which must also provide service. Therefore, most major computer science departments throughout the nation have acquired special medium-sized or somewhat out-dated large computers for their own use (examples: Kansas University, Purdue, Case-Western Reserve). The University of Minnesota will need to do this in the near future.

- Special-Purpose Laboratory Computing is a form of educational computing which is becoming important — and even necessary — in certain specialized professional programs, particularly in engineering. For instance, the use of process control computers has become widespread in the chemical industry. As a result, many chemical engineering departments are using small computers as a piece of instructional laboratory equipment, to control unit operations and provide real-time analyses of chemical engineering systems for students in their laboratory work. In order for engineering education to remain abreast of engineering practice, this kind of educational computing, in which the computer is again a tool rather than an object of instruction, will become more and more necessary. While this type of educational application is now most apparent in a few engineering fields, it is very likely to become a significant factor in other sciences, and especially in the health sciences, over the next decade.

Research Computing

Computers were originally developed as research tools, and over the past two decades they have become indispensible to research in many of the fields pursued in major universities. Research computers can be grouped in three classes.

- General-Purpose Service Facilities available to the entire academic community for research and instruction. The major share of the research computing at colleges and universities is usually handled by computing facilities of this kind.

- Special-Purpose Computing Facilities are configured for and dedicated to specific application areas. Although they may be used for both instruction and research, and generally by students and faculty in certain academic areas, they usually are not suited to or readily available for use outside of these areas. Two examples of facilities of this kind at the University of Minnesota are the CDC 3300 in the Division of Health Computer Sciences, dedicated to and funded largely by the Federal Government for applications in medical science; and the Hybrid and Digigraphics Computer Laboratory, specializing in hybrid analog-digital computation and high-speed interactive computer graphics. Both of these facilities are used and are available for instruction and public service, although the major fraction of their use is for sponsored research. Correspondingly, they are funded largely through federal grants and income from services rendered to sponsored research projects (also mostly federal grants) and outside agencies. (See Appendix H.4 for a breakdown of costs and funding sources. The Division of Health Computer Sciences facility, for instance, was acquired with only 28% university or state funds, while about one-third of its computing load is directly related to instruction of students in the health sciences.)

- Special-Purpose Computing Devices built into research apparatus as part of the apparatus. Such computers are performing functions which cannot be accomplished effectively or efficiently, if at all, by a general-purpose computer. Functionally, they are serving not as computers, but as an integral part of the apparatus in which they are used. A useful analog is a telephone exchange: a modern telephone exchange could be called a computer — the equipment can and does do most of the things a computer does. Functionally, however, it is not a computer, but rather a message-switching device. Because of this functional distinction, and because they are funded almost exclusively by research grants and contracts or service fees, these special-purpose devices will not be considered further as computers.

These are the three categories of research computing facilities. As pointed out earlier, the functions of research and instruction are closely linked for graduate and post-graduate professional education. In this sense, research grants and contracts have contributed an important and substantial subsidy to this kind of education. It is important, therefore, to distinguish as *instructional computing* the unsponsored computing by graduate and post-graduate professional students related to their course work and thesis projects. This is computing for which the State *must* pay if it wishes to provide such advanced training. Sponsored research and other projects directly under the control of faculty members and related to professional activities in their academic field will be defined as *research computing,* even if some graduate students may be involved. This is not the best way to make the distinction, but it is a practical way.

The computer demands of research are that the general-purpose facilities and services be available when they are needed, and at a level sufficient to meet the demands; and that the institutions be organized to allow and assist faculty members to obtain and use appropriate special-purpose computing devices and facilities when outside funds are available for this purpose. Such computer needs should not and have not made demands upon institutional or state funds in any way different from the many other kinds of research activity which are supported from within higher education. For these reasons, this report will not undertake a detailed analysis of research computing in higher education: the service capacity must be there as excess above instructional needs. A major investment of state funds is not required, because most of this computing is supported from outside grants and contracts.

Public Service Computing

Much of the activity normally labeled "research" in higher education actually is a public service, involving development and research activities for public agencies. There are, for instance, many governmental agencies using the various computing facilities of the University of Minnesota, both in the Twin Cities and Duluth. State college regional centers may be expected to undertake many similar activities. Two examples exist for which a facility is almost exclusively dedicated to a public service application.

The IBM 360/30 computer located at the Agricultural Experiment Station in St. Paul is devoted to and funded by services to the Dairy Herd Improvement Association, and for soil analyses, farm management, and other agriculture-related activities. These applications are self-supporting. At the University Hospitals, a Burroughs 2500 computer is dedicated to hospital administrative data processing, patient monitoring, and other internal hospital functions. Again this facility is self-supporting as part of the hospital operations.

Since public service computing within higher education is almost completely supported through the services provided and does not require a direct outlay of state funding through the institutions of higher education, its needs will not be analyzed in this report. The computer capacity and willingness to provide service of a developmental nature must be there, but the required funding will come from the agencies served.

During the course of this study, it became apparent that there were three identifiable areas in which significant planning and development was underway for special applications of computers to the goals of higher education. Development effort devoted to each of the three areas has the potential of leading to more effective service for instruction, research, and public service, and for making the operations of higher education more efficient in providing these services — that is, reducing costs or preventing costs from increasing as rapidly as otherwise. The three special areas are discussed in more detail in Section 3, and two of them are dealt with in special reports appearing as Appendices H.2 and H.3. They are:

- A Statewide Automated Library System.

  The library is a major and expensive learning resource at every college and university, directly serving the needs of instruction, research, and public service. With the recent explosion in volume of printed information, libraries (and especially academic libraries) are being sorely taxed just to keep up with the volume of ordering, processing, cataloging, and shelving, to say nothing of providing adequate reference and retrieval services. To be optimally efficient, however, an automated library must serve the needs of all libraries in the state, not just the libraries in higher education.

- Computer-Assisted Instruction and Computer-Managed Instruction.

  These are direct applications of the computer to the instructional process — using the computer as an integral part of the process to administer and manage instruction. To do this successfully will require a careful assessment of the specific goals, methods, and content of instruction in each course and academic field, followed by an equally careful instructional design to utilize computers and other media in an optimum way. This will require the greatest development effort and will encounter the greatest resistance from those conditioned to traditional methods of instruction. But if successful, these applications also will bring the greatest payoff in terms of effectiveness and efficiency.

- Information Services.

  Information on population characteristics, natural resources, and similar distributed properties of the natural and social worlds is becoming increasingly important for purposes of public and governmental planning at all levels. Likewise, information of this kind, and the ability to process it, is an important learning resource for research and instruction, especially in the social sciences. These latter needs have led to an increasing involvement of faculty members with the development of large data bases of information which can be read and processed by computers. The potential value of information services of this kind, both to higher education and directly to the public, cannot be ignored by a Statewide Study of Computing Facilities in Higher Education, and is, in fact, linked closely to the other two parts of this overall report, covering State Government Agencies and Local Government.

Each of these three special application areas will be discussed in more detail in Section 3 of this report. Recommendations concerning them appear in Section 5.

The Necessity for Computing Facilities and Services in Higher Education

Having discussed the objectives of higher education and the functions that computers can serve in meeting these objectives, it is time to summarize three of the important reasons why computers are a *necessity* in higher education today.

First of all, there is a need for people trained and educated in computer programming and the various other aspects of computer science and data processing. With the size of the computer industry today, this need is obvious, but the size of the need is not. To quote from the 1967 report of the President's Science Advisary Committee, *Computers in Higher Education*.[1]

> There is inadequate information about the number and level of skills of personnel now employed in the field of computers, and there are no meaningful forecasts.
>
> We recommend that the Federal Government collect meaningful data concerning computers and the jobs, personnel, and educational facilities associated with them, and endeavor to make useful annual forecasts.

This recommendation has not been followed. Two articles in a recent issue of the trade magazine *Datamation* quoted rather disparate estimates of the national need for computer personnel:

> 50,000 per year[3], and 125,000 per year[4].

Even considering the present recession in the computer industry, 2% of the lower estimate, or 1,000 per year at all levels, is a reasonable conservative estimate of Minnesota's needs. Existing and planned programs will not saturate this need for some time to come.

Secondly, we need people educated to understand computers, what they can do and how to use them, and how to manage and direct their use in particular areas of application. More specifically, it is doubtful whether society can effectively use, or even tolerate, more social scientists, educational and business administrators, and workers in any number of other fields who are not trained in quantitative methods. Computers in higher education make it possible to train students in all fields in the use of quantitative methods to attack and solve problems.

And finally, there is a need for a general understanding of what computers can and cannot do, and how they affect the society in which we live. It must be understood that an incorrect billing, a lost order, or an inaccurate income tax refund cannot be blamed on computers, but usually are the results of human error. Only when a broad level of public understanding is achieved can the computer begin to reach its full potential. Higher education can help achieve this level of understanding directly by including some exposure to computing in the general education of most students, and indirectly by adequately educating those who will become school teachers and parents and affect the minds of future generations.

OBJECTIVES OF THE STATEWIDE STUDY OF COMPUTING FACILITIES IN HIGHER EDUCATION

Having argued the objectives of and needs for computing in higher education, it is the intent of the remainder of this report to:

- Summarize the existing (1970-71) computing facilities and applications in Minnesota higher education and their costs (Section 2);
- Analyze the needs of Minnesota higher education for computing facilities and services over the next five and ten years (Section 3);
- Determine the costs of various ways of meeting these needs, identifying the least expensive ways (Section 4);
- Recommend specific actions by the institutions and systems of higher education and the legislature to meet the identified needs and lay a sound basis for future development (Section 5).

The entire thrust of this study has been to determine the computing facility and service needs of the post-secondary students of Minnesota, in terms of the *objectives* of higher education, and to find and suggest ways of satisfying these needs which have the greatest likelihood of being implemented. To this end, educators and administrators from numerous institutions in all five systems of higher education and throughout the state were consulted extensively before the recommendations were formulated. The extent of these consultations can be judged from Appendix H.1. There is much evidence, in the form of similar studies in other states, to suggest that plans and recommendations developed without consulting extensively those people and institutions which must eventually implement them are unlikely to be accepted and implemented, regardless of their technical merits. In addition to this consultation within the state, the study benefited from the broader perspective of two consultants from other parts of the country. Dr. Ronald W. Brady, the Executive Assistant to the President of the Ohio State University (and now Administrative Vice-Chancellor of Syracuse University) offered advice on most of the matters related to the study. Dr. Robert M. Hayes, Director of the Institute for Library Research at the University of California and Vice-President of Becker and Hayes, Inc., was consulted on technical and organizational facets of plans for a statewide library automation system.

This study presents some estimates for needed computing facilities and services in isolation from the other important requirements of higher education. The final determination of the weight of the arguments and recommendations here, and the priority of computing among all of the needs of higher education, resides properly with the faculties, institutions, and systems of higher education, the Minnesota Higher Education Coordinating Commission, and ultimately the people of Minnesota through their elected representatives in the State Legislature. If it is generally acceptable, this report can provide guidelines for planning and evaluation by these groups, but it cannot be used *as a plan*. Specific, detailed planning and implementation is the responsibility of higher education, and this report represents only the beginning of that job.

2. A SUMMARY OF PRESENT COMPUTING FACILITIES AND PROGRAMS IN MINNESOTA HIGHER EDUCATION

The 1967 report of the President's Science Advisory Committee – the *Pierce Report*[1] – indicated the need for improvement in computing facilities and programs in higher education, and framed ten recommendations designed to bring the facilities of all higher educational institutions in the United States up to the standards of those schools which were best equipped at that time. These recommendations largely went unheeded, since the recommended federal funds of up to $400 million per year were not forthcoming. In several states *Pierce Report* goals were met to a greater degree than has been the case nationwide. In such cases, however, funds have been supplied by the respective legislatures of those states and have not come mainly from federal agencies. Computing in higher education is currently in a transition phase in this and many other ways: from federal funding toward state funding, from primarily research use toward instruction, and from use by the few toward use by the many.

The situation in Minnesota is not atypical. Most of the institutions of higher education in the state are not nearly so well equipped as the University or Carleton College. Yet even the University fails far short of the *Pierce Report* objectives and lags behind similar institutions in, say, Ohio or Wisconsin. On the other hand, the need for computer education and training may be greater in Minnesota than many other states, since it is a center for the design and manufacture of computers, and has a larger number of technology-based industries than many states.

As pointed out in Section 1, the requirements for computer education and training, and the corresponding programs and facilities at the post-secondary level, vary widely depending on the institution, its goals, and the career intentions of its students. The ensuing discussion will address the five areas or systems of higher education in Minnesota and will attempt to summarize their facilities and programs and to evaluate them with respect to their mission in computer education or training. Computers for administrative data processing will also be summarized.

THE UNIVERSITY OF MINNESOTA

The University is the largest institution of higher education in the state and is the best equipped with computer facilities. These computer facilities are summarized in Table H.5.1 of Appendix H.5, and their uses are summarized in greater detail in Appendix H.4. Three major general-purpose facilities serve the entire university for both instructional and research purposes. These are the CDC 6600 at the University Computer Center and the CDC 3200's at the West Bank Computer Center and the Duluth Campus. The overall instructional use of these facilities amounts to about 45% of their capability. However, their instructional use is growing much more rapidly than their research use (See Appendix H.4). To meet their needs for limited amounts of time-shared computing, which the University has no facilities to provide, several departments and research groups are spending their own supply funds to purchase service from commercial vendors.

Special-purpose computing facilities serve instructional, research, and public service needs but are more specialized in function or service area than the general-purpose facilities. The University's special-purpose facilities include the CDC 3300 of the Division of Health Computer Sciences, the IBM 360/30 on the St. Paul campus, used primarily for agriculture-related public service activities, and the Hybrid Computer Laboratory, with a CDC 1700 serving both a dual analog-digital hybrid computer system and an interactive graphic display system. Administrative Data Processing at the University is served by an IBM 360/50 configuration which, if augmented with additional disc storage, would have sufficient capacity to handle the batch and on-line processing requirements for an institution of this size.

In general, the computer facilities of the University are adequate for the programs underway or planned in the near future, with a few exceptions. The University has one of two undergraduate computer science degree programs in the state and the only graduate program. Especially for the graduate program, a computer is essential for student laboratory work and experimentation. The Center for Research in Human Learning has done considerable research and development in computer-assisted instruction but needs a computer system able to support the continued development and early production phases of this work. The IBM1500 instructional computer system, used for the early phases of their work and funded largely by the National Science Foundation, was discontinued by IBM and the NSF in early June 1970. Finally, the CDC 6600 has considerable unrealized potential for wider service which could be realized by providing central-site hardware and software to support remote terminals, both within the University and at other institutions. Also, it could be further enhanced as a job-shop computer by improving printer facilities. Most large-scale research computers used in an instructional environment are badly printer-bound, and the 6600 is no exception.

THE STATE COLLEGES

The computing capability in the State Colleges has evolved over the past ten years from several electronic accounting machine installations. Current facilities include IBM 1401 installations for administrative data processing, IBM 1620 centers for instruction, and some IBM 1130 computers for both, as shown in Table H.5.2 (Appendix H.5). Most of the existing applications are administrative in nature, leaning heavily toward student record-keeping, with some business or fiscal applications and a few institutional research programs. Approximately 1500 students within the state college system, or slightly less than 5% of total enrollment, are registered each quarter in classes which involve some sort of computer use. Only one of the colleges offers a major in Computer Science; but the others offer mathematics, physics, business, economics, or statistics courses which involve computer solution of problems.

As will be apparent from the analysis in Sections 3 and 4 of this report, the existing (September 1970) computing facilities within the state college system are inadequate by the norms of the *Pierce Report*[1]. However, this situation will be corrected by the major facility to be installed at Mankato late in 1970. If a similar machine is installed in St. Cloud in two or three years, and if the other state colleges have terminals to one of these machines in addition to their current capability, then facilities will be adequate for well over five years[5]. Demand for computer services at the state colleges has not been severe primarily because the available computer resources were so meager as to discourage serious use. The "double-hub" network planned for 1975 or sooner will be a major step toward correcting this situation and will encourage the development of computer and computer-related courses, as well as support the application of information systems technology to the management of the State Colleges.

It may be difficult to justify more than one additional Computer Science degree program in the state college system, and logically that would be located at the college with the second hub. It would be feasible, however, for the other colleges to develop major or minor degree programs in information sciences, management information technology, or elsewhere in the interdisciplinary areas between computer science, the administrative disciplines, and the basic sciences and mathematics. (Moorhead State College, for instance, has a Computer Science option associated with its Mathematics program.)

THE STATE JUNIOR COLLEGES

The State Junior Colleges have a centralized administrative data processing system based on a large IBM 1401 computer. Although this system gives good service, it does have limitations for planned increased enrollment and service levels. Until recently, the junior colleges had no computer service for instruction. Starting in the Spring of 1970, there have been teletype terminals at each college connected to the Honeywell EDINET time-sharing system, as shown in Table H.5.3. The 18 junior colleges share three computer ports. These terminals will support instructional programs and courses for which the computer is used as a tool. The only data processing curriculum in the system is at Lakewood Junior College, the site of the administrative data processing center.

THE PRIVATE COLLEGES

The range of computing facilities and instructional programs in the private colleges runs from more than adequate to non-existent. A few schools are able to expose a hundred to three hundred students to the computer in seven to ten or more courses in Computer Science or computer-related disciplines, as indicated in Table H.5.4.

Although fewer than half of the private colleges and junior colleges employ computers for instruction, most of them use computers, service bureaus, or electronic accounting machines for administrative data processing. Development costs appear high for a college to put administrative applications on a small computer. A group of seven Twin Cities colleges has organized a common program development and coordination effort to reduce these costs[6].

Most of the gaps in computing for private colleges in Minnesota could be closed by coordination of efforts to purchase or develop programs for college administration and by support for terminal facilities at each college and for central or regional computers to service the terminals. Some of the colleges are doing an adequate job with a small IBM 1130 computer and do not really need such terminal support. The University 6600 is available to private college faculty for their research needs on the same basis as it is to the University faculty and is now in the process of being made available via remote terminals at colleges. The Mankato Regional Computer Center will provide similar service.

THE AREA VOCATIONAL-TECHNICAL SCHOOLS

Several of the Area Vocational-Technical Schools have training programs for computer programmers (see Table H.5.5). However, some degree of computer service is also needed at those schools which have one or two-year accounting programs but do not offer programs in data processing. As pointed out in Section 1, data processing curricula in the AVTS have a somewhat different mission than do similar programs in colleges and the University.

There are no obvious gaps in the facilities or programs at the schools with curricula in data processing and with computers (Hibbing, Alexandria, and Mankato). They have excellent facilities and are graduating students well equipped to enter the business world as junior programmers. Those schools with data processing programs using IBM 1401 computers owned by their school district, or computer time donated or otherwise made available by local businesses, as well as schools with one and two-year accounting programs but without computer services adequate for at least COBOL instruction, would be well served with terminals connected to regional computers, service bureaus, or those AVTS with data processing curricula and computers.

OVERALL SUMMARY OF COMPUTING CAPACITY

There are two institutions offering degrees in Computer Science in Minnesota: Mankato State

College offers a B.S. degree, and the University offers B.S., M.S., and Ph.D. degrees in Computer, Information, and Control Sciences. An additional B.S. degree program at St. Cloud State College within the next five years would be tenable in terms of supporting facilities if the second regional center were to be located there. The data processing programs in the Area Vocational-Technical Schools provide instruction in computer technology as it is applied to data processing for business and industry. These programs conceivably might be augmented by one or two more such programs in the new vocational schools soon to open in the Twin Cities area.

On the administrative data processing side of higher education, there are many facilities and much activity but also much redundancy. National efforts are underway to allow comparability of data and use of common program packages. Information systems technology is just now finding its way into college and university management and holds promise for rationalizing the current undisciplined growth of applications, files, and programs into a more consistent approach. The introduction of Program Planning and Budgeting in universities and colleges is also encouraging the information systems approach.

Table 2.1 gives a summary of the major computer facilities currently existing in Minnesota higher education and their costs. A somewhat qualitative approach to placing the present computing capability of Minnesota higher education in perspective is to compare spending with other similar states or states with similar educational expenditures. Over the past five years, from 1964 through 1969, yearly expenditures for computer facilities in Minnesota higher education grew by a factor of four, with the greatest increase coming in 1967. A marked leveling off occurred in 1968 and 1969. Figure 2.1 shows the relative spending levels for computer facilities in the public sector of higher education in selected states during the past five years. Neighboring states were chosen for their similarity to Minnesota in economy, population, and certain higher educational factors. Except for Indiana, the comparisons are not surprising. In recent years public institutions in Illinois, Ohio, and Wisconsin have been somewhat better funded for computer facilities than have their counterparts in Minnesota. However, the differences are not large. In the private sector, Minnesota colleges are relatively worse off, not only as compared to private colleges in other states, as shown in Figure 2.2, but also as compared to publically-supported schools in Minnesota.

The computer industry marketing data from which Figures 2.1 and 2.2 were drawn include federally-funded computer facilities as well as state-funded facilities. It was impossible to separate these factors in the data for all the states shown, but those which were checked indicated that the total value of computers amounted to almost twice the cost of state-supported instructional facilities alone. Since the data were essentially comparable for all the states, it is their relative ranking which is significant.

Table 2.1. Existing Computing Facilities Used for Instruction and Administration in Minnesota Post-Secondary Education, 1970-71 (Includes those approved for acquisition)

Facility	Equivalent Net Purchase Price
UNIVERSITY OF MINNESOTA	
Instruction and Research Systems	
6600(a)(d)	$2,560,000
West Bank 3200(a)(d)	450,000
Duluth 3200(b)	440,000
Health Sciences 3300(a)(d)	825,000
Hybrid Computer(a)(d)	580,000
Time-Shared Computing from Commercial Services	60,000
Administrative System	1,500,000
STATE COLLEGES	
Small Computers (at all colleges)	967,000
Mankato Regional Computer	1,200,000
STATE JUNIOR COLLEGES	
Administrative Computer	163,000
HECC FUNDED PROJECTS(c)	253,700
Junior College Time-Sharing System	
State College Projects:	
Bemidji PDP-8 Mankato Computer Science Curriculum Development Southwest Academic Computing Moorhead IBM 1130 Support St. Cloud Instructional Time-Sharing Test Implementation of CAMPUS Management System	
AREA VOCATIONAL-TECHNICAL SCHOOLS	
Alexandria HW200	221,000
Mankato 360/25	233,000
Hibbing HW200	232,000
Moorhead	10,000
Willmar	40,000
PRIVATE COLLEGES (ESTIMATED)	850,000
TOTAL	$10,624,700

(a) These systems are used both for instruction and research. In Table 5.4, the operating budgets are for instructional usage only. For 1969-70, the instruction versus research usage was as follows: (a) 6600, 31% and 69%; (b) 3300, 33% and 67%; (c) Hybrid 20% and 80%

(b) For planning purposes, these systems are assumed to be 100% instructional.

(c) For both facilities and support.

(d) Significant fractions of the costs of these facilities came from federal or private sources (see Appendix H.4).

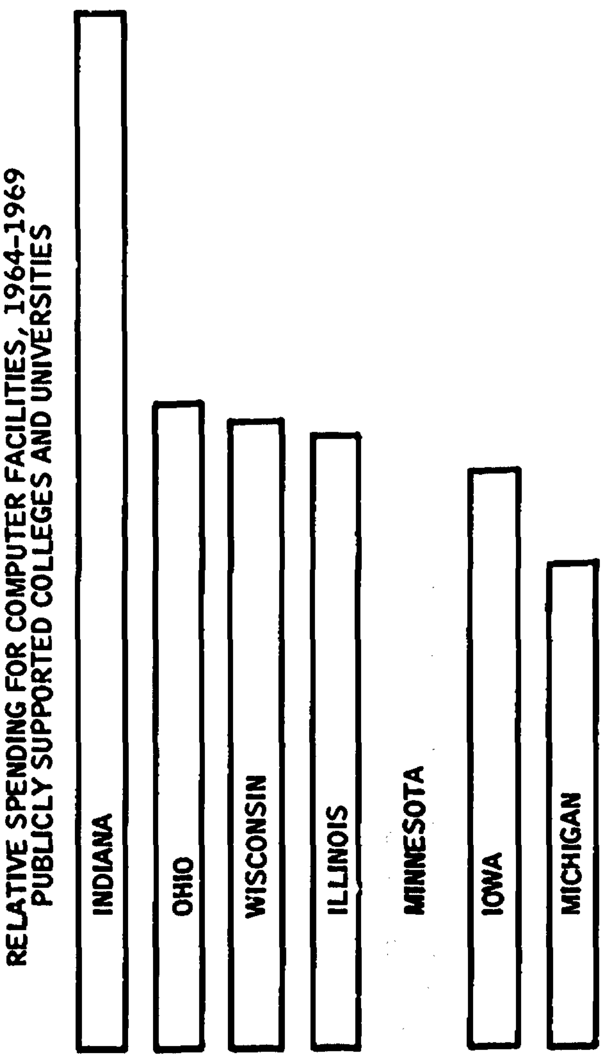


Figure 2.1. *Relative Spending for Computer Facilities, 1964-1969 Publicly Supported Colleges and Universities*

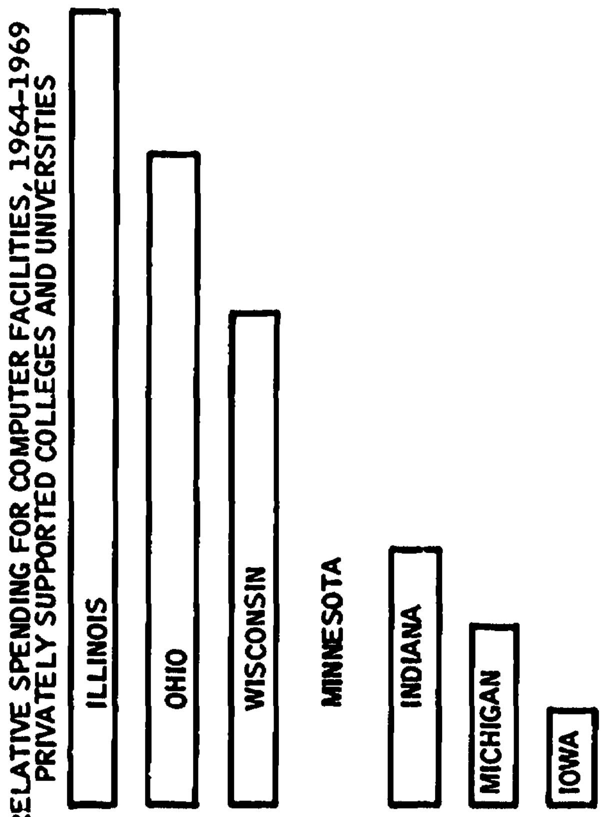


Figure 2.2. *Relative Spending for Computer Facilities, 1964-1969 Privately Supported Colleges and Universities*

3. GOALS AND THE COMPUTER RESOURCES NEEDED TO MEET THEM

How much computing capacity does the State of Minnesota need to provide an adequate level of computing services in higher education? This section presents quantitative estimates of the raw capacity needed in the two major application areas: educational computing (instructional computing and computer training) and administrative data processing. The analysis on which these estimates are based is presented in Appendix H.6; the goals of the estimates are:

- Achievement of the *Pierce Report*[1] objectives for educational computing for the State of Minnesota, i.e., to provide educational computing services for all of higher education in Minnesota equivalent to that available at the leading universities of the nation in 1967-68.
- Establishment of machine-readable data bases and an administrative data processing capacity which is sufficient to support the management information needs of institutions and systems of higher education and lay the basis for program planning and budgeting.

These quantitative estimates of capacity will be presented for the three major hardware components of computer systems:

- Input/output or terminal capacity.
- Central processor capacity.
- Mass storage capacity.

Three special application areas are also discussed: a statewide library automation system; computer-assisted and computer-managed instruction; and general information services.

EDUCATIONAL COMPUTING

Instructional Computing

Instructional computing is the most important area of educational computing for students in post-secondary institutions. For undergraduates the analysis in Appendix H.6 follows the methods of References (1) and (7) based on Minnesota rather than national or hypothetical data. The computing needs of graduate students were also incorporated into the analysis given in Appendix H.6. This analysis first classifies the various academic areas of study as to whether they involve substantial, limited, or casual use of computers. These categories are defined in Table H.6.1, and the major areas of study are classified in Table H.6.2 in Appendix H.6. These degrees of computer utilization by academic area, based on Minnesota student populations, cannot be considered precise. However, there exists no more reasonable basis on which to estimate instructional computing needs at the present time.

Because of the differences in the kinds of programs offered at the area schools and junior colleges, their computing needs were analyzed separately from those of the degree-granting colleges. In applying the results from Tables H.6.2 or H.6.3b in the Appendix, it must be kept in mind that they represent *averages* over a class of students. Although a student enrolled in a course in descriptive biology may use a computer not at all, another student in a beginning genetics course may use it twice as much as the typical "substantial" user.

The analysis in Appendix H.6 averages the number of problems per academic year in Table H.6.1 over the three usage categories weighted by Table H.6.2, showing that 11.3 problems per student are assigned on the computer per academic year. Assuming a 14-hour school day, 200 school days per year and 80% available time on the computer yields 2,240 computing hours available per academic year[7]. This analysis allows one to estimate the computing load for both a time-shared computing system (TS) using inexpensive low-speed terminals and a remote-job-entry system (RJE) with a much smaller number of medium-speed terminals.

Among computer scientists, computer center managers, and computer users there are considerable differences of opinion concerning the relative merits and costs of time-shared and batch-processed computing. Batch processing tends toward optimization of machine and operating system efficiency, while time-shared computing emphasizes the efficiency of the user at some apparent expense in hardware and software. It is apparent to us that most instructional applications of computers can be carried out on a batch processing system, either through remote-job-entry terminals or at the computer site. It is equally apparent that *some* of these applications could be carried out more effectively (in terms of student learning) on an interactive time-shared computer system, and that the educational value of other applications is severely damaged if time-shared computing is not available. Programs in which students interact directly with simulations of engineering, social, business, political, medical, and other systems are prime examples of this latter kind of application: the student decision-making process needs to be on-line with the computer program. It is shown in Appendix H.8 that, if time-shared computing capacity is used with a certain amount of discretion, it is not necessarily much more expensive than batch processing. Without dwelling further on these arguments, this report will proceed on the basis that *both* kinds of computing are necessary to meet the goals of higher education, and in about a 3:1 ratio of batch:time-shared computing.

A time-shared computer system will be defined here in terms of the user; it must include the following characteristics:

- Keyboard input/output, 10-30 characters/second.
- User may interact with his program during its execution.
- Response time of five seconds to a request not requiring significant computation.

The capacity of a time-shared computer system is measured in terms of the number of active terminals.

Table H.6.4 gives estimates of terminal hours per problem[7]. Averaging the loads estimated in Tables H.6.1, 2, and 4 over the three categories and dividing by the total available time yields 150 students per time-shared terminal in a college or university. The same analysis applied to junior colleges (Table H.6.3b) yields 333 students per terminal. Time-shared terminals are not suitable for vocational training in data processing, so their use has not been projected for area vocational-technical schools.

The dedicated computer capacity necessary to serve a given number of low-speed time-shared terminals can best be estimated as the number of active terminals serviced. Over the past several years, experience with several time-sharing systems of various sizes and costs has shown how many active terminals they can service adequately. Experience also suggests an average of one request per active terminal every thirty seconds[7]. Assuming the equivalent of fifteen FORTRAN statements compiled per request and a factor of two to accommodate peak loads leads to a compiling rate of 6.67 statements per second per 1000 four-year college students, and three statements per second for 1000 two-year college students.

The mass storage capacity of a time-sharing system may be estimated by relying on experience at the University of Minnesota and Reference (7), assuming that each active user needs an average of 3,000 characters of storage for his own programs and data. An average of the number of courses using the computer leads to a figure of about 40 percent of the total students in a college using the computer at any one time (Appendix H.6). The analysis indicates a need for 1.2 million characters per 1000 students at 4-year colleges and 600 thousand characters per 1000 students at 2-year colleges.

A remote job entry system employing remote batch access to a regional computer facility can also satisfy the needs established above. An analysis of the required capacity for this mode of operation is given in Appendix H.6 based on Tables H.6.5 and 6 and Reference (7). Assuming medium-speed RJE terminals which read cards and print at about 300 cards and 300 lines per minute, the total number of terminals required to serve 1000 students was estimated as approximately one-half RJE terminal per 1000 students at 4-year colleges.

Carrying out a similar analysis for the more limited needs of students at junior colleges yields about one-sixth RJE terminal per 1000 students. The obvious implication of this figure is that even a single RJE terminal has substantially more capacity than the largest Minnesota junior college needs for instructional computing.

The computer capacity needed to service these terminals is estimated on a peak load basis as 1.2 compiled FORTRAN statements per 1000 four-year college students per second, with 0.4 the corresponding figure for two-year college students.

Another way to furnish remote-job-entry computing is via low-speed terminals rather than medium-speed terminals. Although it is rather inconvenient for students to work with punched paper tape as an input medium from a simple teletype terminal, it can be done. Mark-sense card readers may also be attached to such terminals, increasing both their convenience to students and cost. About 20 low-speed terminals would be equivalent to one medium-speed terminal. The same amount of computing capacity will be needed for remote-job-entry regardless of the speed of the terminals used. The economic and pedagogical tradeoffs between low and medium-speed remote-job-entry and time-sharing are discussed in Appendix H.8.

A mixed time-shared/remote-job-entry system may be a better model of the operation mode of a regional computer center than a system which is only one or the other. As a basis for balancing the two types of usage, the analysis of Section 1.1.3 in Appendix H.6 yields the result that 13.3 time-sharing terminals are equivalent to a remote batch terminal. Assuming an additional 30% overhead factor for the time-sharing mode of operation, the analysis also indicates a requirement for seven times the raw computer compiling power to serve 1000 students in a time-sharing as compared to a batch processing mode. This is currently the mode of operation of the computer at the University of Minnesota — Duluth.

Instructional Computing for Graduate Students

The analyses in References (1), (7), and Appendix H.6 are directed to the computing needs of institutions which offer primarily undergraduate programs. As such, they suffice for all of the institutions in Minnesota except the Twin Cities campus of the University of Minnesota. The state colleges and the Duluth campus of the University all have graduate programs comprising a few percent of total enrollment.

Much of the instructional computing associated with these graduate programs will be course-related rather than large thesis research calculations, and it may be lumped together with undergraduate instructional computing.

The information on computer utilization at the University in 1969-70 in Appendix H.4 shows that graduate students consume a substantial amount of computing capacity not specifically related to their course work.

Using the data from Appendix H.4 on university computer utilization for 1969-70, plus enrollment data summarized in Appendix H.10, it was possible to develop a ratio between graduate and undergraduate student computer needs. This ratio of 3.5 between per-student graduate and undergraduate computing needs will be used, together with the enrollment projections summarized in Appendix H.10, to estimate the total needs of the University of Minnesota for instruction-related computing.

The data processing, computer programming, and computer science programs and courses in all of the systems of higher education provide specific vocational training for their students. The general requirements of these courses and programs have been included in the analysis of Appendix H.6, along with the specific requirements of computer training in the vocational schools. This analysis is based on 1974-75 enrollment projections in accounting and data processing from the State Department of Education. These presume that the 11 existing data processing programs will be increased to 13 by 1974-75, with enrollments ranging from 25 to 150. However, there is some question as to whether this many programs are needed. This issue is addressed in the recommendations in Section 5; but for the analysis in Appendix H.8, the present projections of the State Department of Education have been assumed.

Research Computing

As discussed in Section 1, the two systems of higher education which have a defined mission in research and graduate training are the University of Minnesota, and to a lesser extent, the state colleges. The computer capacity required to provide research services at the University will be excess capacity over and above the instructional computing needs. If the state colleges possess enough computing power to accommodate their instructional needs, they should have little difficulty in providing enough excess time to take care of most of their research needs. Certain particularly large computing or data processing problems may be more economically processed at the University's computer center, or eventually at one of the regional computer centers.

Summary of Educational Computing Needs

Table 3.1 summarizes the number of terminals, the computer capacity, and the special mass storage capacity required to meet the estimated needs for instructional computing of the specific institutions and systems of higher education in Minnesota for the academic years 1969-70, 1975-76, and 1980-81. For 1975-76 and 1980-81, the needs have been scaled according to total enrollment projections from the Minnesota Higher Education Coordinating Commission and the various systems of higher education (see Appendix H.10). The data obtained from these different sources is not always consistent, but any discrepancies and errors are far smaller than other uncertainties in this analysis. If the enrollment projections change significantly for any of the institutions or systems, then the figures in Table 3.1 must be adjusted accordingly. It should be noted that the capacity estimates are properly per 1000 full-time-equivalent (FTE) students, rather than being proportional to total enrollment (headcount). The extrapolation scaling is based, therefore, on the reasonable assumption that the ratio of FTE to total enrollment is constant from 1969 to 1981.

ADMINISTRATIVE DATA PROCESSING

An administrative data processing system for an institution or system of higher education will consist of data bases containing information for the following areas:

- Student Records
- Staff and Payroll
- Financial
- Courses and Curricula
- Space
- Property Inventory

Table 3.1. Summary of Terminal and Peak Load (
for Instructional Computing in Minnes

Institution or System	1969-70 Enrollment (FTE)	Time-Shared System: No. of Terminals	Time-Shared System: Peak Computer Capacity (FORTRAN Statements Per Second)	Remote Job-Entry System: No. of Terminals	Remote Job-Entry System: Peak Computer Capacity (FORTRAN Statements Per Second)	Projected Enrollment (FTE)	Ti[...] No. Term[...]
UNIVERSITY OF MINNESOTA	44,610	460	460	34.6	83.0	56,364	6
Twin Cities							
Undergraduate and Professional	33,519	224	224	16.8	40.3	38,000	2
Graduate	8,160(a)	190	190	14.3	34.3	11,520(a)	2
Duluth	5,279	35	35	2.6	6.3	8,050	
Morris	1,565	10	10	0.8	1.9	2,930	
Crookston	459	1	3	0.1	0.2	1,014	
Waseca	-	-	-	-	-	600	
STATE COLLEGES	35,528	237	237	17.7	42.7	46,090	3
Bemidji	4,652	31	31	2.3	5.6	5,790	
Mankato	10,960	73	73	5.5	13.2	13,640	
Moorhead	5,249	35	35	2.6	6.3	7,000	
St. Cloud	8,863	59	59	4.4	10.6	11,160	
Southwest	2,153	14	14	1.1	2.6	4,100	
Winona	3,651	24	24	1.8	4.4	4,400	3
PRIVATE COLLEGES (4-YEAR)	27,627	184	184	13.8	33.2	33,800	22
Typical	1,000	6.7	7	0.5	1.2		
STATE JUNIOR COLLEGES	15,914	48	48	2.6	6.4	26,173	7
Typical	1,000	3	3	0.2	0.4		
TOTALS	123,679	929	929	68.7	165.3	161,227	1,21
AREA VOCATIONAL-TECHNICAL SCHOOLS (HEADCOUNT)	13,435(b)	-	-	23	84 Terminal Hours/Day	20,449	

(a)Total enrollment figures have been used for graduate students, rather than full-time equivalents, for reasons explained in the text.
(b)See Appendix H.6 for an explanation of the Area Vocational-Technical School requirements. Terminals may be business minicomputer or regular terminals, or small stand-alone computers. AVTS headcount projections are for 1974-75 and 1979-80.

:mputer Capacity Requirements
:a Post-Secondary Institutions

1975-76				[illegible]				
-Shared System		Remote Job-Entry System			Time-Shared System		Remote Job-Entry System	
:f :nals	Peak Computer Capacity (FORTRAN Statements Per Second)	No. of Terminals	Peak Computer Capacity (FORTRAN Statements Per Second)	Projected Enrollment (FTE)	No. of Terminals	Peak Computer Capacity (FORTRAN Statements Per Second)	No. of Terminals	Peak Computer Capacity (FORTRAN Statements Per Second)
:2	602	44.8	107.8	66,610	734	734	54.9	131.6
:4	254	19	45.6	42,400	283	283	21.2	50.8
'0	270	20	48.4	14,865(a)	347	347	26.0	62.4
4	26.8	4.0	9.7	10,400	69	69	5.2	12.5
9	97	1.5	3.5	4,150	28	28	2.1	5.0
3	1.5	0.2	0.4	1,560	5	5	0.25	0.6
2	0.9	0.1	0.2	800	2	2	0.12	0.3
8	308	23.0	55.4	58,040	387	387	29.6	69.6
9	39	2.9	6.9	7,180	48	48	3.6	8.6
1	91	6.8	16.4	17,000	113	113	8.5	20.4
7	47	3.5	8.4	8,710	58	58	4.9	10.4
4	74	5.6	13.4	13,870	93	93	6.9	16.6
7	27	2.0	4.9	5,750	38	38	2.9	6.9
0	30	2.2	5.3	5,530	37	37	2.8	6.6
5	225	16.9	40.5	37,200	248	248	18.6	44.6
9	79	4.2	10.5	32,200	97	97	5.2	12.9
4	1,214	88.9	214.2	194,050	1,466	1,466	108.3	258.7
		24	146 Terminal Hours/Day	39,850(b)	-	-	24	164 Terminal Hours/Day

Various applications programs access one or more of these files to produce automatically the reports, forms, records, checks, and other documents and data required for the administrative operations of the institution or system. Within higher education in Minnesota, the University of Minnesota has what is perhaps the most complete data processing system in operation and in the process of implementation. For this reason, and because adequate information was not as readily available from other sources, the University's system was taken as the basis for an estimate of the computer system capacity required to provide complete data processing services to all institutions in the state.

The units in which this capacity has been estimated are:

- Mass storage, in characters or bytes
- Input, in cards or similar record entries per year
- Output, in lines per year
- Computer transactions per year
- Required output rate, in lines per minute
- Required computing capacity in computer transactions per minute

The last two items are the limiting factors on computer system performance and, following the practice of Reference (7), these factors were estimated including peak load demands. The definition of a "computer transaction" was taken from the Auerbach Reports[8]; it consists of retrieval of a file from a random-access mass storage device (disk), updating the file, and returning it to mass storage and to a report file.

Details of the administrative data processing capacity analysis, complete with annotations on the various assumptions made in scaling the results to the different institutions, may be found in Appendix H.6. Summaries of the total capacity estimates for 1969-70, 1975-76, and 1980-81 appear in Table 3.2. The overall capacity results are assumed to scale within a system of institutions and with time according to the total enrollment. From an examination of the details in Appendix H.6, it will be seen that several other more relevant factors are used to scale various data file sizes or applications capacities. However, all of these factors increase and decrease with head-count. To facilitate scaling of the individual private colleges and state colleges, the figures are given in the tables in terms of a private college with 1000 students and a state college with 10,000 students. Area vocational-technical schools have not been included in the estimates of administrative data processing needs because their needs are unlike those of the other institutions of higher education, and they are parts of local independent or intermediate school districts. (See Section 2 in the Local Government part of the overall study.)

All of the factors entering into Appendix H.6 and Table 3.2 were reviewed by data processing management staff at the University, the State College Board, one state college, and one private college. Despite numerous questions concerning specific details, the estimates were confirmed as reasonable by these reviewers.

SPECIAL APPLICATIONS

As mentioned previously, the three special applications areas related to higher education and treated in this study are automated library systems; computer-assisted and computer-managed instruction; and information services.

A Statewide Automated Library System

The goals of a comprehensive statewide library system are to furnish several kinds of services to all libraries in the state through a centralized processing facility. The major kinds of services to be provided can be classified as:

1. Catalog production – production of Union Catalogs of holdings and of serials (periodicals).
2. Technical processing – book ordering and preparation, cataloging, and card production.
3. Information services – retrieval of bibliographic and archival information from available machine-readable data bases, such as the Chemical Abstracts, Library of Congress tapes, and archival census bureau tapes.
4. On-line bibliographic services for libraries throughout the state, providing rapid access and updating of holdings and other bibliographic information to all participating libraries.

All of these services are to be based eventually on a common bibliographic data base which will form the core of the system. Because of the magnitude of the job of assessing the technical soundness of the plans developed by the University Library Systems Staff, and identifying viable solutions to some of the serious interlibrary organizational problems that were apparent, an outside consultant who is a specialist in library systems was retained – Dr. Robert M. Hayes of Becker and Hayes, Inc., and Director of the U.C.L.A. Institute of Library Research. On the basis of an intensive three-day visit to the Twin Cities and the documentation produced by the University Library Systems Staff and various other librarians, libraries, and library agencies in the state, Dr. Hayes submitted a brief report and recommendations, which appear as Appendix H.2 of this study.

During and after his visit and subsequent to distribution of his report to a number of the library people involved, we have received numerous comments on Dr. Hayes' evaluation of Minnesota's statewide library automation plans. As far as the goals set forth in the Hayes Report are concerned they are agreed upon as good and necessary by the people concerned with libraries in the state. The overall development effort required to achieve the goals has been estimated by Hayes in Tables 5 through 9 of Appendix H.2, in terms of dollars per year. It ranges from $700,000 for the first year to $3.3 million in the fifth year; after this investment for development has been made, the operation would continue on a service-for-fee basis. The investment in a statewide library system probably will not reduce the costs of library operation overall, but it can greatly improve the services libraries can provide. And, if there is wholehearted participation and cooperation by all of the major public and academic libraries, then the costs of library operations can be prevented from escalating rapidly at the same time that service deteriorates. For example, if this central service were available it would not be necessary for each library in the state to acquire its own technical processing capability. On the basis of Dr. Hayes' report (Appendix H.2) and the reactions to it and to his visit, recommendations related to a statewide automated library system are made in Section 5 of this study. In addition, some comments appear there on the problems of organizational structures for operations across system boundaries, as they apply to library automation and as they are reflected in the Hayes Report.

Table 3.2. Need Estimates for Administrative Data

	1969-70						
	Headcount	Mass Storage (Millions of Characters)	Required Output (Lines/ Minute)	Required Peak Computer Capacity (Transactions/ Minute)	Number of Query Terminals for Student Registration	Projected Headcount	Ma Stor (Milli o Charac
UNIVERSITY OF MINNESOTA	50,415	660	986	2,200	101	63,050	82
Twin Cities	42,884				85	50,150	
Duluth	5,580	36	54	123	11	8,500	4
Morris	1,510				3	2,800	
Crookston, Waseca	441				2	1,600	
STATE COLLEGES	37,681	328	496	1,067	76	48,844	42
Bemidji	4,716	41	62	133	10	5,857	5
Mankato	12,090	105	159	343	24	15,045	13
Moorhead	5,235	46	69	148	11	6,988	6
St. Cloud	9,557	83	126	270	19	12,028	10
Southwest	2,206	19	29	63	4	4,209	3
Winona	3,877	34	51	110	8	4,717	4
STATE JUNIOR COLLEGE SYSTEM	17,544	123	215	422	36	29,080	20
PRIVATE COLLEGES (4-Year)	27,137	400	325		–	33,189	49
Typical	1,000	11	12		2	1,000	1

rative Data Processing Capacity in Minnesota Colleges

1975-76				[redacted]				
Mass Storage (Millions of Characters)	Required Output (Lines/ Minute)	Required Peak Computer Capacity (Transactions/ Minute)	Number of Query Terminals for Student Registration	Projected Headcount	Mass Storage (Millions of Characters)	Required Output (Lines/ Minute)	Required Peak Computer Capacity (Transactions/ Minute)	Number of Query Terminals for Student Registration
827	1,240	2,790	126	74,350	885	1,460	3,280	149
				57,050				114
45	68	188	100	11,000	49	80	244	22
			17	4,000				8
			3	2,300				5
426	645	1,383	97	61,412	533	808	1,741	123
51	77	166	12	7,286	63	96	206	15
131	199	426	30	18,713	163	247	532	87
61	92	198	14	8,691	75	115	246	17
105	159	341	24	14,961	130	197	424	30
37	56	119	8	5,895	51	77	167	12
41	62	133	9	5,866	51	76	166	12
204	356	698	60	35,450	248	435	851	71
490	398	1,290	–	36,427	538	437	1,420	–
11	12	39	2	1,000	11	12	39	2

2

Computer-Assisted Instruction

As discussed in Section 1 of this report, the computer can be used not only as a tool by students (instructional computing), but also as an inherent part of the educational process — as a device to present material, problems, and decision situations and respond to a student's answers, solutions, and requests on the basis of his individual performance (computer-assisted instruction, or CAI) — and as a device to aid a teacher in managing the progress of a student through an instructional experience tailored to his individual needs (computer-managed instruction, or CMI). Whether the computer can be efficient and effective in these tasks is not yet known; there are optimists and skeptics both. It is imperative that higher education find out whether it is feasible to use computers in this way, for two reasons.

Firstly, the computer has the potential to enhance greatly the effectiveness of education in certain fields — to increase the effectiveness and efficiency with which students learn certain kinds of skills and concepts, as in foreign language and some areas of medical science; and to accommodate the presentation and pace to the different needs of individuals. Secondly, the computer may be an efficient, less expensive way to provide education in those areas where it is effective, as compared with traditional methods in higher education. A major cost in education is the cost of highly-trained manpower, which is largely determined by prevailing salaries and wages based on productivity of goods and services in other parts of the economy. In higher education there is no "product" with an easily-defined market value in the usual sense. And there has been, until recently, no way of increasing "productivity" in higher education to keep the total cost from soaring to levels that represent a significant burden to the taxpayer, the parent, and the student. Computer-assisted and computer-managed instruction offer the *potential* for significant economies to reduce the rate at which the costs of higher education increase. Although success cannot be guaranteed, the potential payoff is great enough to justify, or even demand, a modest investment for research and development.

On the basis of this kind of assessment of the economies and effectiveness of higher education, as well as some limited experience in the medical sciences, the Ohio State University has recently decided to make a substantial investment in CAI development and has acquired a computer system costing about $25,000/month (Class D in Table H.7.1) for this and other instructional resource applications. With a much smaller investment over the past two years, the Center for Research in Human Learning at the University of Minnesota has developed a staff with more experience and, in our opinion, a much sounder fundamental understanding of the basic and applied problems of instructional design and CAI than exists at Ohio State, or at any but a very few universities in the world.

The Executive Officer of the Minnesota Center for Research in Human Learning, Professor Russell W. Burris, has prepared for this report a paper which appears as Appendix H.3. His paper summarizes in greater detail the potentials of CAI for effectiveness and efficiency; some of the questions to be answered and development problems to be solved before it should be implemented on more than an experimental basis; the costs of this development; and some of the potential per-student costs if the development succeeds. The eventual costs which Professor Burris cites — $0.34 to $1.60 per student hour — are less than or comparable to the present costs of conventional instruction. However, they possess the notable advantage that costs of computer applications tend to decrease (or at least remain constant) as technology advances, while wage rates, upon which the costs of traditional instruction are based, change in the opposite direction.

In addition to this activity in CAI, two Minnesota institutions — Southwest Minnesota State College and Macalester College — are planning development efforts in the computer management of training for school teachers. This offers similar possibilities for increased effectiveness and attention to the needs of the individual student, as well as efficiency in terms of cost economies. It is expected that the development efforts at these two colleges would benefit substantially from contact with and support from the Center for Research in Human Learning.

The specific recommendations of this report on CAI and CMI development, based on these considerations and on Professor Burris' paper in Appendix H.3, may be found in Section 5. The goals toward which these recommendations are directed are four:

1. To find out whether CAI or CMI can significantly increase the effectiveness of higher education in specific fields and more nearly tailor the instructional materials and strategies to the diverse individual needs of students;
2. To establish the real costs of CAI and CMI and determine to what extent these represent savings which will slow the rise in total costs of higher education;
3. To involve faculty members from all systems and institutions of higher education in the state in the development effort, and to disseminate information on the work so that results may be adopted and adapted to as many institutions as possible and as quickly as they are proven to be efficient and effective;
4. To develop pilot programs in a number of disciplines, and to establish CAI learning centers from which formal instruction is available using CAI and CMI technologies.

Information Services

Several information retrieval projects have developed in various departments of the University of Minnesota as a part of their research programs. Some of these, such as the Diabetes Information Center in the School of Medicine, are very specialized. However others, such as RAFT (Rapid Analysis Fiscal Tool) and MAPS (Minnesota Area Planning Service), are much more general in nature and could serve statewide information needs which are much broader than the research programs of certain departments or schools. At the present time these information services are in a developmental rather than operational or "production" stage, and thus are in the proper research province of the University; however, as they near operational status and begin to attract a clientele from industrial firms and government agencies, they should be funded and managed like other statewide information services and resources.

Perhaps the best way to encourage the development of RAFT and MAPS and carry them into operational status would be to fund them through the Computer Services Division of the Department of Administration by means of contracts to the University departments involved in their development. As these systems become operational, then the State can take over their management as a statewide information resource.

4. FACILITIES AND COSTS TO MEET THE GOALS

This section will summarize the kinds of facilities available in mid-1970 to meet the goals estimated in Section 3 for the instructional computing needs of Minnesota higher education, and for providing the administrative data processing capacity needed for efficient and effective college management and program budgeting. The facilities and order-of-magnitude cost estimates for the computers themselves will be identified in terms of remote-job-entry (RJE), time-sharing (TSS), and mixed (RJE and TSS) systems. For administrative data processing and vocational school computing, both batch processing and the RJE mode of operation are considered. Much of the supporting detailed analysis for this section is contained in the tables in Appendix H.7.

It is not the intent of this report to configure computer systems in detail to meet the specific needs of institutions but rather to give general indications of the kinds of facilities needed for various applications and their costs. The mention of specific hardware does not mean that the hardware configuration will necessarily perform the task indicated at the cost given. This kind of information is included only to provide a general idea of the size of the system involved for those who are familiar with computer systems. The cost estimates could easily be low by a factor of two or high by 25%. In other words, this report can provide useful feasibility and background information of a general nature, but it should *not* be used as the basis of a system design.

COMPUTER SYSTEMS

Table H.7.1 in Appendix H.7 establishes a scale of computer systems according to their raw computing and data processing capacities and their cost ranges. This scale ranges from Class A – the most powerful and expensive computers available today – through Class I at the opposite extreme. Figure 4.1 displays the contents of Table H.7.1 in graphical form. The results summarized in Table 3.1 for instructional computing, and in Table 3.2 for administrative data processing, have been converted into the units used in Table H.7.1 and Figure 4.1. In Tables 4.1, 4.2, and 4.3 are displayed the estimated computer capacities required to achieve in 1975-76 the goals of Section 3 for Minnesota higher education. The approximate costs shown in these tables are for the computer only; they do not include terminals, operating support, or any of the other indispensible items discussed below. Furthermore, the computer costs are based on commercial rates and do not reflect the educational discounts and federal grants which often substantially reduce these costs to the state.

Each of the three tables shows a different way of achieving the goals:

Table 4.1: Systems which support only batch processing via local and remote terminals. However, it is not feasible to use medium-speed remote-job-entry terminals for junior colleges. The largest of them in 1975-76 (about 3000 FTE students) could use only half the capacity of a terminal, and two-thirds of them would use a terminal to less than 20% of capacity. Therefore, these colleges (and the Crookston and Waseca campuses of the University) will require service from a Class Z time-shared computer, as in Table 4.3, at a hardware cost of about $14,000/month.

Table 4.2: Systems which support time-shared and batch computing on the same computer. Reasonable assumptions are made concerning the fraction of instructional computing on each campus which would be in each of these modes.

Table 4.3: Separate computer systems to support batch processing and time-shared computing. This arrangement is based on the observation that most instructional uses of time-shared computing involve small programs or programs which require interactions with the user during execution rather than large amounts of computation. Programs requiring large amounts of scientific computing are run more effectively, more quickly, and at less cost in a batch processing mode. Hence, the power and variety of programming languages and systems available on a large computer are not needed for instructional time-sharing. The least-expensive Class Z time-shared system can be used to serve these needs.

Table H.7.1 and Tables 4.1 through 4.3 require a number of comments. First of all, the capacity and system cost figures in Table H.7.1 are all very approximate. They are based upon benchmark tests published in the Auerbach Reports[8], on other published information, and on the personal experience of the staff of Analysts International Corporation. Computer systems of specific manufacturers are mentioned only to provide some relation between the table and the real world. Depending on the application, a particular computer at a specific price may perform considerably better or worse than the table indicates, or than another computer with which it is classed.

Figure 4.1 shows that, with the exception of the largest computer systems (Class A and B), the rate of compiling FORTRAN statements increases in direct proportion to costs. In the middle of the range, the data processing capacity increases more rapidly than this, but that is not true for small or large computers. Neither the compiling nor the data processing rates rise as fast as predicted by Grosch's Law, for which a doubling of cost is accompanied by the quadrupling of the raw computing (arithmetic) capacity. This is because the computing associated with both administrative data processing and instruction is much more dependent on input/output and manipulation and interpretation of non-numerical information than is the straight scientific computing to which Grosch's Law applies.

The required computer capacities listed in Tables 4.1 to 4.3, in units of FORTRAN statements compiled per minute, represent the minimum compiling and computing speed for satisfactory instructional service during the busier times of the year. In Section 3, a peak load factor of two was included in these numbers, which means that if all instructional computing were distributed uniformly over a 14-hour day, 200-day academic year, then the computer capacity required would be about one-half that listed in Tables 4.1 to 4.3. Such a uniform distribution is clearly impossible in practice and, were it attempted, would destroy the educational effectiveness of the computer for all but a few students and faculty. As long as this kind of rigid, uniform scheduling is not applied to other educational resources, such as classroom, office, and laboratory space; expensive laboratory and audio-visual equipment; library facilities; and

Table 4.1. Estimated Computer Capacities R
with Batch-Processing and Remot

	Administrative Processing Required	
	(Lines/minute)	(Transactions per minute)
UNIVERSITY OF MINNESOTA	1,240	2,790
Twin Cities		
Duluth	68	188[e]
Morris		
Crookston, Waseca		
STATE COLLEGES	645	1,383
Bemidji	77	166
Mankato	199	426
Moorhead	92	198
St. Cloud	159	341
Southwest	56	119
Winona	62	133
STATE JUNIOR COLLEGE SYSTEM	356	698
Typical Junior College (Enrollment ≃ 1,000)		
PRIVATE COLLEGES	398	1,290
Typical Private College (Enrollment ≃ 1,000)	12	39

[a]For administrative processing only.

[b]For instructional computing only, including Twin Cities and Morris campuses.

[c]State college needs could also be handled by:
1) a Class D computer for instruction + Class E for administrative processing, at a total of $65,
2) two Class D's at regional centers, providing about 70% of one as excess capacity, at $80,00

[d]To provide the two-year campuses with instructional time-shared computing under this plan would ad hardware.

[e]Assumes 50% of total Duluth workload processed locally and the remainder in the Twin Cities.

Estimated Computer Capacities Required to Serve Minnesota Higher Education
with Batch-Processing and Remote-Job-Entry Facilities in 1975-76

e Processing Required		Instructional Capacity Required			
te)	(Transactions per minute)	Number of Terminals	(FORTRAN Statements/minute)	Computer Class Required (Table H.6.1)	Approximate Monthly Lease Cost $
	2,790	–	–	E+[a]	30,000
		39	5,640	C or 47% of B[b]	65,000 (C) or 40,000 (47% of B)
	188[e]	4.0	582	F	12,000
		1.5	210	–[b]	–
		0.3	36	–[d]	–
	1,383	23.0	3,320	D+[c]	45,000
	166	2.9	414	G	8,000
	426	6.8	985	F+	15,000
	198	3.5	504	G	8,000
	341	5.6	805	F+	14,000
	119	2.0	294	H+	6,000
	133	2.2	318	H+	6,000
	698	4.2[d]	–[d]	F-[a,d]	10,000[a,d]
		0.16		–	–
	1,290	17	2,440	E+	30,000
	39	0.5	72	I+	3,500

ampuses.

e processing, at a total of $65,000/month, or
as excess capacity, at $80,000/month.

nputing under this plan would add about $14,000 per month for

ainder in the Twin Cities.

Table 4.2. Estimated Computer Capacities Required to
Time-Sharing and Remote-Job-Entry, Batch

	Administrative Processing Required		Instructional Time-Shai	
	(Lines per minute)	(Transactions per minute)	% TS	N Te (A
UNIVERSITY OF MINNESOTA	1,240	2,790	–	
Twin Cities			25	
Duluth	68[d]	188[d]	25	
Morris			50	
Crookston, Waseca			100	
STATE COLLEGES	645	1,383	25	
Bemidji	77	166	25	
Mankato	199	426	25	
Moorhead	92	198	25	
St. Cloud	159	341	25	
Southwest	56	119	25	
Winona	62	133	25	
STATE JUNIOR COLLEGE SYSTEM	356	698	100	
Typical Junior College (Enrollment ≃ 1,000)	–	–		
PRIVATE COLLEGES	398	1,290	25	
Typical Private College (Enrollment ≃ 1,000)	12	39	25	

[a]For administrative processing only.
[b]For instructional computing only, Twin Cities and Morris campuses.
[c]Morris, Crookston, and Waseca are accommodated on the Twin Cities campus computer.
[d]Assumes 50% of Duluth workload processed locally.

…acities Required to Serve Minnesota Higher Education in 1975-76 with …e-Job-Entry, Batch-Processing, Using the Same Computers for Both

Instructional Capacity Required Time-Shared Computing			Instructional Capacity Required Batch Processing via Remote Job-Entry				
% TS	No. TS Terminals (Active)	(Statements per minute)	% Batch	No. RJE Terminals	(Statements/ minute)	Computer Class Required (Table 4.1)	Approx. Monthly Lease Cost $
–	–	–	–	–	–	E+[a]	30,000
25	131	10,380	75	30	4,230	B[b]	85,000
25	14	511	75	3	436	F	12,000
50	10	383	50	1	105	c	
100	5	426	0	0	0	c	
25	77	3,020	75	18	2,489	C	65,000
25	10	382	75	2	310	F	12,000
25	23	900	75	5	739	E	25,000
25	12	462	75	3	378	F	12,000
25	19	736	75	4	604	F+	16,000
25	7	270	75	1.5	220	G	8,000
25	8	290	75	2	238	G	8,000
100	79	2,350	–	–	–	E+	30,000
25	55	2,230	75	12	1,830	D+	52,000
25	2	66	75	1	54	H-	4,000

Table 4.3. *Estimated Computer Capacities Required to Serve Minnesota ... Sharing and Remote-Job-Entry Batch-Processing, Using Separ...*

	Administrative Processing Required		Instructional Capacity Required Time-Shared Computing			Ins... Batc...
	(Lines Per Minute)	(Transactions Per Minute)	% TS	No. TS Terminals (Active)	(Statements Per Minute)	% Batch
UNIVERSITY OF MINNESOTA	1,240	2,790	–	–	–	–
Twin Cities			25	131	10,388	75
Duluth	68[d]	188[d]	25	14	511	75
Morris			50	10	383	50
Crookston, Waseca			100	5	426	100
STATE COLLEGES	645	1,383	25	77	3,020	75
Bemidji	77	166	25	10	382	75
Mankato	199	426	25	23	900	75
Moorhead	92	198	25	12	462	75
St. Cloud	159	341	25	19	736	75
Southwest	56	119	25	7	270	75
Winona	62	133	25	8	290	75
STATE JUNIOR COLLEGE SYSTEM	356	698	100	79	2,350	–
Typical Junior College (Enrollment ≃ 1,000)	–	–				
PRIVATE COLLEGES	398	1,290	25	55	2,230	75
Typical Private College (Enrollment ≃ 1,000)	12	39	25	2	66	75

[a]For administrative processing only.

[b]For instructional computing only, Twin Cities and Morris campuses.

[c]Assume a Class Z time-shared computer, the hardware cost of which is $6,000/active terminal, or $150/month per active terminal. This does not include operating support.

[d]Assumes 50% of Duluth workload processed locally.

Serve Minnesota Higher Education in 1975-76 with Time-
sing, Using Separate Computers for the Two Modes

	Instructional Capacity Required Batch Processing via Remote Job-Entry			Computer Class Required (Table 4.1)		Approximate Monthly Lease Cost for Computers		
ts	% Batch	No. RJE Terminals	(Statements/ Minute)	Time-Shared[c]	Batch	Time-Shared $	Batch $	Total $
	–	–	–		E+[a]			30,000
3	75	30	4,230	Z	D-[b]	20,000	50,000	70,000
L	75	3	436	Z	F-	2,100	9,000	11,100
3	50	1	105	Z		2,250	–	2,250
5	100	0	0					
)	75	18	2,489	Z	D	11,550	35,000	46,550
2	75	2	310	Z	H+	1,500	5,000	6,500
)	75	5	739	Z	F-	3,450	10,000	13,450
:	75	3	378	Z	G	1,800	8,000	9,800
5	75	4	604	Z	F-	2,850	10,000	12,850
)	75	1.5	220	Z	H+	1,050	4,500	5,550
)	75	2	238	Z	H+	1,200	5,000	6,200
)	–	–		Z	F-[a]	11,850	10,000	21,850
)	75	12	1,830	Z	E	8,250	25,000	33,250
5	75	1	54	Z	I+	300	3,000	3,300

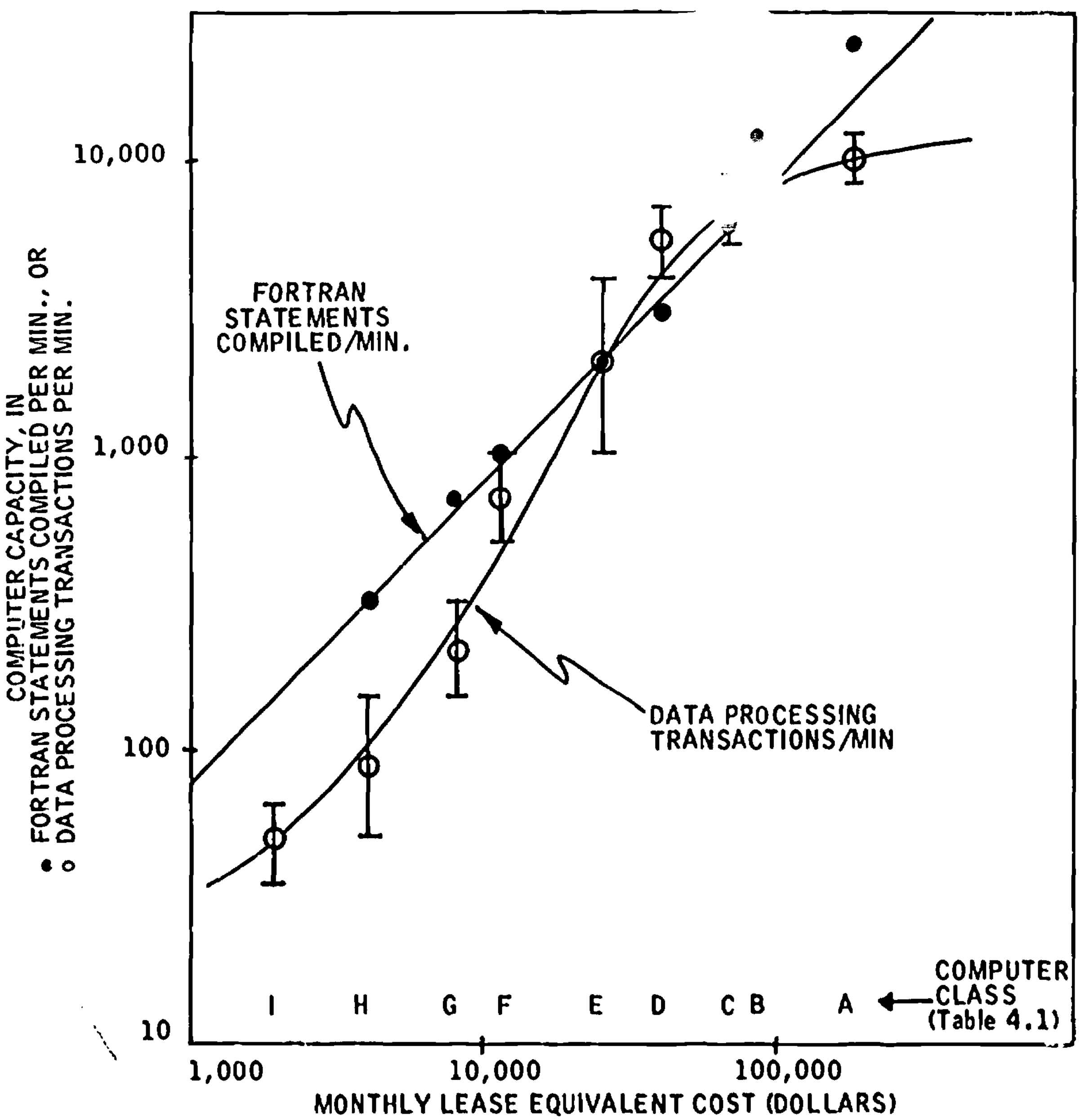


Figure 4.1 Computer Capacity Versus Cost

meal schedules and facilities, then it cannot be expected to work for computers. On the other hand, the peak load factor of two will not eliminate significant queuing and delays during busy periods, providing students with considerable incentive to work during non-rush hours. It is thought that the factor of two is a reasonable compromise between minimum cost service which is educationally inadequate, and maximum convenience service which is too expensive.

With this definition of computer capacity in mind, it will be noted in Table 4.1 that to adequately service their instructional needs in 1975, the Twin Cities campus of the University of Minnesota will require a computer with just under half of the compiling capacity of their existing Class B CDC 6600. About half of the computing at the University is for faculty research and public service applications (see Appendix H.4); it is expected that this will continue to be true over the next decade. It appears that this research and public service load can be accommodated in that half of the effective computer year outside of the 200 14-hour school days, plus in the background time available during school days. Users from other institutions of higher education can probably be serviced during this background time, too, at a higher priority level than lengthy research and public service jobs. But with all these demands on it, the capacity of the University's computer will be pressed in 1975. We expect that it will need to be expanded or replaced with a larger computer early in the second half of this decade. This analysis is consistent with that made by Dr. Frank Verbrugge, Director of University Computer Services, using an entirely different and independent method, and included as Appendix H.4 of this report.

Another interesting observation from Table 4.1 and Figure 4.1 is that the University's Class B computer is, in fact, more economical than a smaller system more nearly matched to the actual instructional needs of the University. The Class A and B computers, which were designed specifically for efficient FORTRAN compiling and large scientific and engineering calculations, lie in fact substantially above the capacity-versus-cost graph for smaller systems (Figure 4.1). By moving to a computer with 50% less capacity, which would handle the instructional load for the university in 1975 and very little else, it would be possible to save not 50%, but rather about 18% of the computer costs. In addition to the very substantial reduction in all research and public service applications, this move would sacrifice both the capacity to process efficiently certain kinds of large scientific and engineering design problems for which the Class B computer was designed, and the federal government's contribution of 31% of the computer's purchase price specifically to support this capacity at the University (see Appendix H.4).

It appears from Table 4.1 that there is a considerable cost saving associated with a centralized state college computer ($52,000/month) as opposed to computers at each state college (a total of $68,000/month). This cost saving, however, will be partly offset by the additional communications lines required to link four or five state colleges to centralized facilities. These tradeoffs will be dealt with in more detail later.

A comparison of Tables 4.2 and 4.3 indicates that it is considerably more economical to provide time-shared computing from a small Class Z system dedicated to that kind of service than it is to provide it from a large computer, whether that large computer is used also for batch processing (Table 4.2) or is dedicated to time-sharing (Table H.7.1b). This is one place where economies of scale do not appear, provided that the service needs of time-sharing users are limited to relatively small jobs in a limited variety of programming languages. As mentioned above, this does tend to be true of instructional time-shared computing. The results in Tables 4.1, 4.2, and 4.3 show that it is just slightly more exoensive to furnish some of the instructional computing via a Class Z time-shared system than entirely by batch processing, while there is a considerable cost increase associated with providing the same amount of time-shared computing on the same computer which supplies the batch processing. These comparisons are shown more directly for the state colleges and the University in Table 4.4. In Appendix H.8, a more complete comparison of time-shared computing and various kinds of remote-job-entry computing is given.

Finally, a general observation may be extracted from the comments above. The greatest computer efficiency can be achieved by using a machine especially designed for a particular kind of job and avoiding a mix of different kinds of computing on the same machine. Hence, instructional time-shared computing is least expensive on a small, dedicated system; large scientific calculations are best carried out on the extremely fast Class A or B computers which were designed for such applications; and administrative data is most efficiently processed on computers in Class D or E, at the knee of the cost-capacity curve in Figure 4.1.

MASS STORAGE

Mass storage for data and programs is an indispensible and expensive feature of any general-purpose computer system. In the past, punched cards have been used as the mass storage medium for many computer systems, especially small ones. This medium is needlessly bulky and difficult to handle, store, and access. The two common mass data storage media at present are magnetic tape and magnetic discs or drums. The important difference between these two is that data must be accessed sequentially on magnetic tape but can be retrieved at random from any location on a disc or drum. Hence, tape is an effective and inexpensive medium for storing information which is usually referenced in serial or sequential order. High-speed disc and drum storage is far more effective when fast and frequent access to randomly distributed data is required.

The computer systems in the scales of Table H.7.1 include appropriate mass storage for the usual instructional computing applications. In particular, the time-shared computer systems are configured with enough disk capacity to provide about 3000 characters of program and data storage for each user.

The amount of data storage required for administrative applications is quite large and, therefore, is listed separately from the computer capacity. Approximate costs for mass storage units and the control units required to connect them to a computer are listed in Table H.7.2. Using the mass storage estimates from Table 3.2 and monthly costs for typical storage systems from Table H.7.2, the amount and cost of mass storage is shown in Table H.7.3 for each of the systems of higher education. Rather than using average or typical cost estimates, monthly costs of particular mass storage systems were employed, since in most cases the computer system with which the storage subsystem would work was

Table 4.4. A Comparison of Three Ways of Supplying the Computer Capacity Required at the University of Minnesota and at the Minnesota State Colleges. Computer Cost Estimates are Monthly Lease Equivalents Extracted from Tables 4.1, 4.2, and 4.3.

	Batch Processing Only	Batch plus 25% Instructional Time-Sharing on Same Computer	Batch plus 25% Instructional Time-Sharing on Class Z TSS Computer
University of Minnesota, Twin Cities (Instructional Computing Only)	$65,000/mo.	$85,000/mo.	$70,000/mo.
State Colleges-Centralized System for Instructional and Administrative Computing	$45,000/mo.	$65,000/mo.	$46,550/mo.

known. It was assumed that only 40% of the storage requirements given in Tables 3.2 or H.7.3 would have to be on-line at one time, and this is reflected in the monthly cost estimates given in Table H.7.3.

There is one major consideration which increases the cost and difficulty of storing and maintaining administrative data in a computer system — security. Special attention must be given to the use of hardware devices (memory protect), software and operating system design, and procedures for maintaining duplicate backup records to prevent unauthorized access to data and to minimize the possibility of accidental or intentional destruction of data. The costs of attention to this matter are intangible and are usually lumped into system operating support and maintenance. The costs of overlooking the security problem are intolerable.

INPUT/OUTPUT FACILITIES: TERMINALS AND COMMUNICATIONS

Configuration of Remote-Terminal Computer Systems

A remote-terminal computer system is rather more complicated than it may appear to the casual user or observer. Figure 4.2 illustrates the components in a typical system involving multiple terminals of both the low-speed time-shared and medium-speed remote-job-entry variety. A system dedicated to serving only one kind of terminal simply will not have any of the hardware attached to the other kind of terminal. The low-speed terminals are assumed to transmit at ten characters/second or about 110 bits per second (bps) — the standard teletype transmission rate. The medium-speed RJE terminals will be assumed to function at a rate of 2400 bits per second, corresponding to an input/output rate of about 300 cards/minute or 300 lines/minute, assuming fifty characters per card or line.

The components involved in a system of the kind illustrated will be described individually in terms of what they do and about how much they cost. It should be kept in mind that the prices quoted are typical prices, and that prices of components from various manufacturers, which can do more or fewer useful things than may be illustrated here, may vary from those quoted by factors of two or more.

Terminals

This is the basic input/output device. The simplest and least expensive terminal today is a teletype (TTY), which can be had with or without a paper tape punch and reader for off-line preparation and fast, automatic transmission of input data. Although a TTY can be used for remote-job-entry, it is rather slow and inefficient for this application; it is usually used for time-shared computing, providing the capability for preparation and debugging of programs and interaction with programs during their execution. Card and mark-sense document readers and graphic recorders are available which can be controlled by TTY terminals to increase their efficiency or effectiveness. Also becoming more available are terminals and accessories which operate at thirty characters per second. These are much more effective for large amounts of output and input via punched tape or mark-sense cards.

At the other end of the spectrum is a terminal consisting of a small computer with the ability to preprocess and format input data for more efficient transmission and utilization of the central computer facilities. Table H.7.4 displays the spectrum of terminal types, their approximate costs, and some examples of terminals currently in widespread use. The terminal classes have been identified with lower-case letters, ranging from Class h, including the most powerful and expensive small computers which are likely to be used as terminals, down to Class m, the slowest and least-expensive terminal (a teletypewriter).

Multiplexors or Concentrators

A single telephone line is able to handle data transmission at rates of 2000 to 2400 bits per second with no special equipment, and at rates of up to 9600 bps with special modems and line conditioning. A multiplexor is a device which

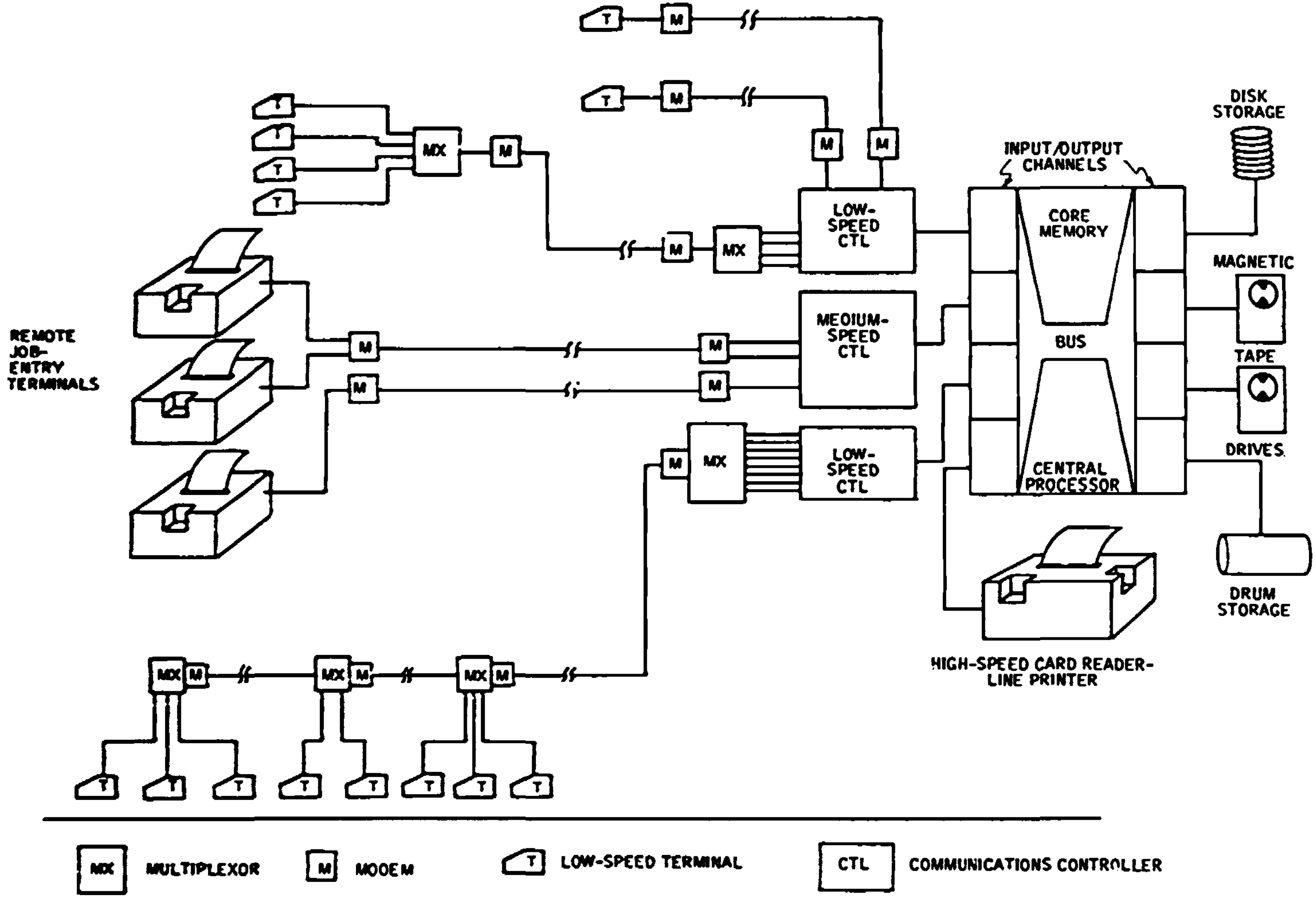


Figure 4.2. Configuration of a Remote Terminal Computer System

permits the output from two or more terminals to be combined for transmission over a single telephone line, often allowing substantial savings in communications costs. For instance, it is possible to concentrate as many as 16 to 24 low-speed teletype terminals (110 bps) into a single "voice grade" telephone line, and two medium-speed 2400 bps RJE terminals into a single telephone line. At the other end of the line (the computer site), a similar multiplexor will be required to separate the incoming signals into the original multiple-terminal channels. Table H.7.5 in Appendix H.7 describes a variety of types of multiplexors and their costs.

Modems or Data Sets

For transmission over telephone lines, the pulses from terminals must be converted into audio tone signals. At the other end they must be converted back into electrical pulses for transmission into the computer. The device which accomplishes this transformation in both directions is called a modem (modulator-demodulator), or data set, or Data-Phone (Bell System trade name). Modems are designed to operate at specific data transmission rates – the faster the rate, the more expensive the modem. Modems are also designated as synchronous or asynchronous, depending on whether or not the series of tone pulses representing a character are transmitted one at a time, or in blocks of characters with the pulse timing strictly controlled by a clock oscillator. Some multiplexors have modems built into them, so that they do not need to be supplied separately. The characteristics of several different kinds of modems are described in Table H.7.6 of Appendix H.7.

Communication Lines

The only sources of communication lines for data transmission within the state at present are the common carriers, Northwestern Bell Telephone Company, other private telephone companies, and Western Union. Within the next ten years it is possible that other communications carriers may offer data transmission service, and it is a recommendation of this report that a study be made of the feasibility of a statewide network for communications of all kinds between all units of government and education. For our purposes here, however, we have no choice but to describe the characteristics and costs of presently-available communication line services.

This information is listed in Table H.7.7 for the facilities appropriate to data communications in higher education. These are all voice-grade lines. It is unlikely that higher education itself would generate enough data traffic over any route to warrant the much more expensive wide-band transmission lines handling 40,000 bits/second and up. (However, the communications needs of all governmental agencies could cost-justify such lines over certain high-traffic routes. This possibility will be a major part of the feasibility study of a statewide communications network.) Certain data links will be used for rather limited amounts of time for which the regular long-distance dial-up network will be more economical than leased-line or WATS (Wide Area Telephone) service. An example is a state college with a computer tying into the University's 6600, particularly in the early stages of such an inter-institutional arrangement. The information in Table H.7.7 will enable institutions to determine when it becomes more economical to switch from dial-up to another form of service. The GSA lines in Table H.7.7 are lines leased at bulk rates by the federal government and made available at very low cost to agencies of state and local government when and where extra capacity exists. Information on the availability of these lines between the locations of most institutions of higher education is maintained by the Telecommunications Division of the State Department of Administration.

Finally, the state itself now leases a number of communications lines to serve the needs of its various agencies and offices throughout the state. These lines and facilities are tabulated in Table H.7.8, and it may be possible to arrange for limited use of a few of them for data communications. Since these lines are intended for voice communications between offices, they are not available during normal daytime hours;

and in some cases they must be kept open after hours as well. Unfortunately, the WATS lines from St. Paul are OUTWATS, while for communications between a terminal and a computer, INWATS lines are needed. Since the heavy need of large numbers of students for instructional computing must be accommodated during the day, the presently-existing leased lines will be of little use. They may be of major importance, however, for processing certain kinds of long research calculations from remote locations where both terminals and an available state tie-line or WATS line happen to be located.

Communications Controllers or Concentrators

When data arrives at the computer from remote locations, it must be collected and concentrated into bunches of complete data records (i.e., complete lines of input or messages) and fed into the computer in a high-speed stream or a fast burst; otherwise the processing speed of the computer would be slowed down by many orders of magnitude to match the data input rate from a single terminal. The device which accomplishes this task is a communications controller or concentrator. The characteristics and costs of some typical controllers are listed in Table H.7.9. A controller is, in effect, a message processing and switching computer. Some of the more effective teleprocessing computer systems, in fact, employ small "front-end" computers as concentrators. This is another example of a computer being dedicated, effectively and efficiently, to a task other than computing.

Staffing of Teleprocessing Networks

Any teleprocessing computer network involving more than a few remote terminals and communications lines must be designed and engineered with some care, installed, and maintained. This is especially true of networks using multiplexors and medium-speed and multi-channel modems. If all of the equipment is obtained from one of the common carriers, then their monthly rates will include the design, installation, and maintenance of the system. When equipment is leased from other vendors, they usually will provide routine maintenance as part of the lease cost; if purchased rather than leased, most vendors offer maintenance contracts on their equipment for a monthly fee. But if a network is as complicated as those to be described later for a junior college-private college-university time-shared computing service, or for a multi-user interconnected state college system, then the communications network must either be leased from the telephone company or Western Union, or the managers of the system must obtain staff to design and supervise the installation and maintenance of the communications. The minimum staff for this purpose would be one highly competent communications engineer. This staffing problem must not be forgotten when comparing costs of common carrier and independent vendor facilities.

A similar problem arises with the maintenance and servicing of terminals and other communications hardware. At some point, when there is enough equipment of this type, it may become more economical to hire a technician or two to maintain and service it rather than paying a monthly service charge to the vendor. Decisions on such matters should weigh not only costs, but also service and reliability. An instructional computing network *must* be reliable if it is to be educationally useful and effective. Recent reports from several NSF-funded regional computer networks in higher education have documented the importance of careful design and maintenance of the communications part of the network as well as the computer part[9].

At present, communications engineering support would have to be provided by whatever group is responsible for operating a communications network – a state college or the university, for instance. A capacity to provide this kind of service to higher education as well as other governmental agencies may develop in the State Telecommunications Division. This division may, in fact, develop the capacity to design, implement, and manage a complete communications system linking a terminal to the communications controller. These possibilities will be under study during the coming months.

STAFF AND OPERATING SUPPORT

One of the major components of cost in any computer installation is the operating support — staff salaries, maintenance, and general supplies and expenses which are too numerous to detail. Any estimate of the cost of computing which ignores these expenses will be highly misleading. In a business or industrial environment, medium and large-scale data processing installations seem to incur operating costs which are about twice the monthly rental cost of the hardware they use. Estimates made at the University of Minnesota's Computer Center show operating costs (salaries, maintenance, supplies and expenses) about equal to the equivalent monthly rental of the equipment. For small data processing installations in business and industry, operating costs may be considerably greater than two times the equivalent monthly rental[10].

Experience indicates that computer operations in higher education require somewhat less staff support than in business, because much programming is done by faculty and students as part of their job instead of by paid programmers and analysts. At the least, this is true for educational applications of computers. To estimate operating costs for educational computing, it has been assumed that operating costs equal equivalent monthly rental costs at prevailing commercial rates (not including educational discounts). The monthly rental includes the computer system, mass storage, terminals, and communications, while operating support covers keypunches (five or six for each remote-job-entry terminal, or per 2000 students) and other input peripherals, as well as staff salaries, maintenance, supplies, and expenses. Administrative data processing is assumed to require twice the equivalent monthly rental in operating expenses.

DEPLOYMENT ALTERNATIVES

Procedures and Assumptions

The number of ways in which the educational and administrative computer resources of higher education *could* be deployed is indefinitely large. The number of alternatives has been scaled down to manageable size by employing the criterion of educational effectiveness, by recognizing the existence of computing facilities at certain locations now, and by some gross cost considerations. The resentments and vested interests occasionally encountered between or within the systems or institutions were given no weight. As discussed more extensively in Section 5, these and other political considerations may make certain alternatives entirely unworkable, *unless* a user-directed policy board is established for facilities serving several institutions.

Some complex organizational factors must be addressed if inter-institutional and inter-system services such as the statewide library system and regional computer centers are to be workable. Such experiments have been shown to be workable in other states, e.g., libraries in Ohio and regional computer centers in Iowa. The key to success in such an endeavor is a user-oriented organization. If services are offered to a group of users on a "take it or leave it" basis, the services will probably be left. The potential users of a forthcoming inter-institutional service center must be brought into the cooperative venture before it is established, and in such a way that they have a real sense of participation. One organizational approach is to elect a governing board from representatives of the users or potential users and to have the director or executive committee of the service organization report to this board.

The systems alternatives have been configured to meet the computing goals defined in Section 3 for 1975, using the hardware capacities and costs and operating support levels established earlier in this section. Even if money were no object, it would be impossible to meet the goals and to develop the staff and the faculty expertise to use the capacity earlier than 1975.

Finally, we have considered *only* the needs for instructional computing, computer training in the Area Vocational-Technical Schools, and administrative data processing in the collegiate institutions. We have *not* taken into account any involvement of users outside of higher education, such as is planned for the center at Mankato State College. Where there is no excess capacity for such users, it will have to be provided if they are to be accommodated. This may well justify the acquisition of larger facilities than those described here. But then the outside users would pay their share so that the total cost to higher education will not be affected much. Where there is excess capacity by a factor of two or greater, the facility *may* be too large in 1975, unless outside users are brought in. When the excess capacity is less than a factor of two, the facility may be about the right size or it may be too small. If the estimates here are as precise as a factor of two, it is only by luck.

Specification of the Alternative Deployment Configurations

In this section each of the five systems of higher education in Minnesota will be discussed in turn, indicating which alternatives we have chosen for analysis and why. Details of the analysis of each alternative may be found in Appendix H.9; a summary of the results follows discussions of the five systems.

University of Minnesota

In 1975, about 25% of the post-secondary students and almost all of the graduate and advanced training in the state will be concentrated on the Twin Cities campus of the University of Minnesota. It is assumed that the administrative data processing (most of it for all campuses of the University) is confined to a separate, dedicated batch processing facility with a capacity for about one dozen remote query terminals. To our knowledge there are no major universities at which administrative and instruction-research computing have been combined on one machine, and a few where it has been tried and failed. The total amount of computer capacity needed at the University also makes this division sensible.

For instructional computing on the Twin Cities campus, we have made the following assumptions:

1. A configuration of three high-speed input/output stations exists (one on the West Bank, one in the engineering complex, and one elsewhere on the Twin Cities campus) and serves 30% of the instructional computing needs. This requires three high-speed telephone lines.
2. A network of remote-job-entry terminals is connected to the batch processing computer over voice-grade telephone lines and serves 45% of the instructional needs.
3. Interactive time-shared computing is required for about 25% of the computing capacity. These needs are satisfied by local telephone lines to a central time-shared facility which costs about $6,000 per active terminal (or about $150/mo. equivalent lease).

In addition to this instructional capability, the University will need, very approximately, an equal amount of capacity for its research and service computing. Since the cost of this computing will be charged to those activities, it will not be included in the cost estimates here.

At present, about 15% of the work on the Duluth computer is administrative processing which must be carried out locally. This amounts to approximately 35-40% of the total Duluth administrative work load, the remainder being handled in the Twin Cities. It will be assumed that in 1975 60% of the administrative data files are used and maintained locally, as well as in the Twin Cities, and that 50% of the administrative work load is processed in Duluth. Instructional needs will be accommodated by a local batch input/output station (75%) and low-speed teletype terminals (25%). Duluth has had its own medium-sized (Class F) computer for two years. As shown in Tables 4.1-4.3, this campus needs the capacity of such a computer, and will probably outgrow it soon after 1975. The expense of a high-speed communications line to provide this capacity remotely from the Twin Cities would exceed substantially any cost savings resulting from use of a large central computer. By 1975, Duluth should be provided with a voice-grade telephone line to Minneapolis for administrative query terminals and occasional remote entry of large problems on the University's major computer. Excess capacity may be needed to serve users outside the UMD campus, as a regional computing center.

The instructional computing needs at the Morris campus in 1975 can be satisfied by a combination of time-shared and remote-job-entry terminals, each accommodating 50% of the load and served by leased telephone lines. These lines can also service a query terminal to the University's administrative computer. The instructional terminals could be connected to any suitable computer in the state. For instance, tying into a regional center at St. Cloud State College would save a few hundred dollars per month in leased line charges over a connection to the Twin Cities. At the moment, the main University campus seems to be the only source of adequate service.

The computer needs of the University Technical Colleges in Crookston and Waseca most resemble those of junior colleges. In the 1975 deployment schemes, they have been provided with time-shared terminals to the university-managed computer on the same basis as the State Junior Colleges.

The University deployment configurations analyzed are:

U-1: A system with computing facilities in the Twin Cities and Duluth serving all of the University's needs.

U-2: A regionalized system with the two technical colleges and the Morris campus tying into the nearest regional computing center ·· er than into University facilities.

State Colleges

The State College Board's plan is to have two regional computing center hubs in operation by 1975[5]. The first of these will be implemented at Mankato State College in 1970. It is assumed in one case that the second hub will be in service at St. Cloud State College in 1975, and in another case that only the Mankato computer will be available then. Each of the satellite state colleges have been assumed to possess a Class I computer which functions as a stand-alone computer and a terminal (Table H.7.3). Three of them now have (or have on order) IBM 1130 computers. It is also assumed that the satellite colleges possess Class k terminals for communicating on a remote-job-entry basis with a large computer elsewhere — usually one of the state college hubs.

Although there may be a real demand for time-shared service at the state colleges with satellite computers, it is assumed that they use only batch processing service through remote medium-speed terminals or local high-speed terminals (one high-speed terminal is equivalent to about four medium-speed devices). Replacement of 25% of this capacity with the equivalent number of low-speed terminals for time-sharing would add a relatively small cost to the total. A 14-hour day is available for instructional work by students, with an 8-hour shift for administrative applications at all locations.

The configurations evaluated for the state colleges, then, are as follows:

S-1: Two regional computing center hubs, with the state colleges linked by WATS lines.

S-2: Two regional computing center hubs, with the state colleges linked by telephone lines.

S-3: A single regional computing center hub at Mankato, with leased-line connections to other state colleges.

S-4: A single regional computing center hub at St. Cloud, with leased-line connections to other state colleges.

State Junior Colleges

Administrative data processing has been centralized for the State Junior College system and despite inadequate equipment has provided a very high level of service to its customers (the junior colleges and the State Junior College Board). Because many of the junior colleges are small and geographically remote, it seems most reasonable and economical to maintain centralization of data processing, using United Parcel Service as the communications link for transmitting most of the data. The centralized data processing could be directly under the control of the Junior College Board, or they could lease an appropriate amount of service from some other facility in the Twin Cities. Suggestions on this will be found in Section 5. But it is necessary that the data processing staff be under the State Junior College Board and that they have control of their own data base. In 1975, the Board offices in the Capitol Square Building will need direct access to the computer data base for retrieving information and for carrying out various kinds of statistical studies. For this purpose, they should be able to use the terminal installed by the State College Board. Finally, sometime after 1975 each junior college will need a query terminal for retrieval, checking, and updating information on their own students and budgets. These query terminals are not included in the 1975 configuration.

For instructional computing, many of the junior colleges are so small that one remote-job-entry terminal would far exceed their needs. Furthermore, time-sharing and cooperative access to and development of a common library of instructional programs are effective ways of providing a rather uniform level of instructional computing service to all junior college students.

The three deployments presented in Appendix H.9 for the State Junior College System are therefore:

JA-1: A centralized administrative system, using mail and parcel service for most data communications.

JI-1: A centralized time-shared instructional computing system serving all 20 junior colleges. (The computer facility would be shared with the private colleges and the University.)

JI-2: A regionalized time-shared computing network, with the junior colleges tied into computers located in Duluth, Mankato, St. Cloud, and the Twin Cities.

Private Colleges

Deployment of computer resources to serve the needs of the private colleges is a more speculative projection than in the case of the public institutions, since the colleges are so varied and dispersed. In the Twin Cities there is a group of colleges large enough and strong enough to profitably cooperate and share their resources. This they have already begun to do for both instructional computing and administrative data processing. Several of these colleges also have been using the University's computer facilities, and arrangements are being made to expand this usage substantially. Similar strength, in quality if not in numbers, exists in the Northfield area. The other private colleges are more scattered.

The deployment alternative P-1 shown without costs in Appendix H.9 represents what seems to be the most natural arrangement for the private colleges on a geographical basis. Note that the regional centers planned for Mankato and St. Cloud should have enough capacity to accommodate their neighboring private colleges in 1975. The realization of a deployment like this depends on the readiness of the public institutions to share their resources; the availability of funds, both public and private, to support use of resources; and the response of the individual private institutions. A specific recommendation in the next section deals with the first two conditions.

Area Vocational-Technical Schools

The need for computing capacity in the Area Vocational-Technical Schools has been summarized in Table H.5.3a of Appendix H.5.

Following the projections of the State Department of Education, it has been assumed that in 1975 there will be about thirteen area schools with data processing and accounting programs; three area schools with large (two-year) accounting programs; and eight more with small (one-year) accounting programs. It has been assumed further that the suggested deployments of computing capacity will provide not only enough access, but also excess capacity to serve other regular training programs which may require some exposure to computers: for instance, surveying, drafting, numerical machine control programming, job estimating in carpentry and other trades. Some of the schools also have extensive adult evening programs in accounting and data processing, especially in the larger population centers. It is assumed that the resources serving the day-school population will be adequate for evening students, but the added cost of this extra use has not been included in these deployment estimates.

In Appendix H.9, the following deployment schemes are presented for the area schools:

V-1: A single central computing facility serving all area schools needing service, via remote-job-entry terminals and WATS lines. This alternative is the one suggested without analysis or documentation in the 1969 ARIES Report on data processing in the vocational schools. This alternative has been analyzed in terms of business mini-computers (Class I terminals) at those locations with data processing or large two-year accounting programs, and Class k remote-job-entry terminals at other locations.

V-2: Service through remote terminals from regional computing centers located in the Twin Cities, Duluth, St. Cloud, and Mankato.

V-3: Service from a combination of small (Class H) computers at some of the area schools already processing them; business mini-computer terminals at other schools with data processing and large two-year accounting programs; and simple remote-job-entry terminals (Class k) at schools with accounting programs.

A Fully Regionalized Deployment for Higher Education

Several of the alternatives examined for each of the systems of higher education have involved regional centers providing computing service. This last deployment configuration, R-1, combines each of the regional configurations U-2, S-2, JI-2, and V-2 to summarize the total networking and cost implications of a fully regionalized system for the public institutions. This kind of a system should not be considered until at least one regional center has demonstrated that it can meet the goals of instructional computing for many institutions in a way that is reasonably satisfactory to users of the service provided.

Summary of Results for the Deployment Alternatives

The costs associated with each of the configurations described in the previous section and analyzed in Appendix H.9 are summarized in Table 4.5. These rough cost estimates are based on July 1970 projections of enrollments in 1975 and are one factor considered in arriving at the recommendations in the next section of this report.

In interpreting and comparing the costs in Table 4.5 with other estimates in this report, it is important to keep a number of facts in mind.

- Only instructional computing in the public institutions, computer training in the vocational schools, and administrative data processing in the public collegiate institutions have been included. Special-purpose training and laboratory computers, public service and research computing, library automation, and computer-assisted instruction development have been excluded.
- Staff and operating support costs have been assumed to equal monthly hardware costs for all kinds of computing except in the vocational-technical schools. As remarked elsewhere, the 1:1 ratio is appropriate for instructional computing, while a 2:1 operating-to-hardware ratio is

Table 4.5. Summary of Monthly Equivalent Lease Costs Associated with Each of the Deployment Configurations Analyzed (1970 Dollars)

Configuration and Description		Computer Systems	Mass Storage	Terminals	Communications	Operations and Staff[d]	Total
U-1	Intra-University System	109,750	5,848	32,400	12,088	160,086	321,072
U-2	Regionalized University System	114,350[a]	5,848	32,400	11,830	164,428	328,856
S-1	State College System with Two Hubs, INWATS	60,000	9,114	9,600	8,380	87,094	174,188
S-2	State College System with Two Hubs, Leased Lines	60,000	9,114	9,600	7,240	85,954	171,908
S-3	State College System with One Hub at Mankato	60,500	9,114	12,800	11,564	93,978	187,956
S-4	State College System with One Hub at St. Cloud	60,500	9,114	12,800	10,996	93,440	186,880
JA-1	Central Administration System for Junior Colleges	10,000	1,333	-	-	11,333	22,667
JI-1	Central Time-Sharing for Junior Colleges	12,300	(b)	6,150	4,849	23,299	46,598
JI-2	Junior College Time-Sharing Using Regional Centers	13,650*	(b)	6,150	4,696	24,496	48,992
P-1	Private Colleges[c]						
V-1	Area Vocational-Technical Schools Using Central Computer	12,800	(b)	48,100	18,938	(d)	79,838
V-2	Area Vocational-Technical Schools Using Regional Centers	7,900	(b)	48,100	8,520	(d)	64,520
V-3	Area Vocational-Technical Schools Using Small Computers and Terminals	14,500	(b)	43,100	7,718	(d)	65,318
R-1	Fully Regionalized System	195,900	14,962	96,250	31,366	274,878	613,356

(a) These costs are based on expected average utilization rather than peak load capacity.
(b) Mass storage for instructional systems is included in the cost of the computer systems.
(c) Costs have not been estimated for the private colleges as a system. The computing and terminal capacities needed for individual colleges can be estimated from Tables 4.1 – 4.3. Communications costs will be quite low, because all private colleges are near regional centers (except Concordia, which could ride an unused channel on one of Moorhead's lines to St. Cloud).
(d) Staff and operations cost is assumed to equal the sum of the other costs, except for the Area Vocational-Technical Schools. AVTS computing facilities are staffed by regular faculty members as part of their teaching duties, and by students as part of their instructional program, not by specially-hired operators, programmers, and managers, as is the case in the other systems.

more suitable for administrative processing, and about 2:3 for small dedicated time-shared computers. Both of these other applications are relatively small, and the overall picture has not been changed greatly.

- Costs quoted for computers are based on market value, *not* on what the institution or the State actually paid. For instance, the University paid about 55% of market value for its Class B computer, of which 45% came from a federal grant (see Appendix H.4), and Mankato is planning to lease its Class D machine at about $20,000/month rather than the $40,000 class rate in Table H.7.1. The differences arise from variations in costs of computers in the same class, and from discounts and grants by the manufacturer. The operating support for these facilities, however, should be based on market value rather than discounts.

A close examination of Table 4.5 permits several other interesting observations.

- Regionalization of computer services does not appear to result in large savings for the University or the Junior College System; the decrease in communication line cost is small because of the geographical distribution of institutions and is partly offset by increased cost of computer services from regional centers, rather than from dedicated Class Z time-shared computers or from the University's super-efficient Class B computer. There do seem to be savings for a two-hub state college system as opposed to a single hub, for a regionalized vocational-technical school network a centralized system, and for the University Technical College in Crookston and Waseca connected to a junior college network rather than to other computers of the University (see the R-1 configuration in Appendix H.9). These conclusions, however, *could* be changed by a number of developments: for instance, availability of GSA telephone lines, implementation of a statewide communications network, regionalization not just within higher education but involving other public agencies, dispersal rather than centralization of Class Z time-shared computers. With the exceptions mentioned and on the basis of presently available communications facilities, then, it would seem that the matter of regionalization vs. centralization could be settled on the basis of educational effectiveness rather than cost.

- If the Pierce Report goals for adequate computing are met in 1975, then the cost per student of computing at the University will be about 1.7 times that in the state colleges (see Table 5.6 in the next section). This reflects primarily the high cost of graduate and post-graduate professional training in terms of computing, as well as all of the other resources consumed by this form of advanced education.

- On a per-student basis, computing in the state colleges, junior colleges, and vocational-technical schools costs about the same. It would be noticeably less in the junior colleges except that the separate administrative computer there is rather more expensive than administrative computing in the state colleges. When it is recalled that only about 10% of the students enrolled in vocational-technical schools are in data processing or accounting courses, the cost per student who actually uses the computer becomes ten times the average cost per student in the collegiate institutions. This matter will be discussed in greater detail in Section 5.

- It is apparent from these considerations that the State Junior College System can reduce its administrative costs either by utilizing a large computer facility outside the system, or by selling its excess capacity to other users in the state or in higher education.

Several of these observations will be referred to or elaborated upon in Section 5, in terms of the more complete computing cost projections there.

5. RECOMMENDATIONS AND DEVELOPMENT SCHEDULES

This final section of the report on higher education contains:

a) A series of recommendations for actions or policies — in general, for each of the five systems of higher education, and for the Higher Education Coordinating Commission;

b) A rather specific five-year schedule for developing computing capability in Minnesota higher education, complete with order-of-magnitude cost estimates;

c) A more general indication of developments during the second five-year period, 1975-1980;

d) Some comparative information on other cost figures in higher education to place the cost estimates from (b) in perspective; and

e) Suggestions for priorities and planning to use the funds which may become available.

In a certain sense, the section could be considered a "Master Plan" for computers in Minnesota higher education. The recommendations and funding estimates, however, must be thought of as guidelines; they must not be used as rigid, specific plans. The scope and time available to complete the study have not been sufficient to develop specific, detailed implementation plans, which in any case are the responsibility of the institutions and systems themselves. What the report attempts to do is to estimate the computing capacity required for many of the major functions and areas of higher education in Minnesota, to assess the approximate cost of providing this capacity, to recommend alternatives for its deployment throughout the state, and to discuss some of the problems and organizational structures associated with implementing the recommendations.

The scope of this part of the study excluded even a general survey of the computer needs of elementary and secondary education. Even though some post-secondary institutions plan to provide computer services to schools and other outside agencies, the capacity and cost to provide these services have not been taken into account. Any such plans will naturally require capacity in excess of the needs of higher education. If this excess capacity has not been included in our estimates, then it will have to be provided. If it has been included, then it will be the responsibility of those managing the facility to insure that, in the long run, the excess capacity is utilized effectively, and that its incremental cost to higher education is recovered.

RECOMMENDATIONS FOR MINNESOTA HIGHER EDUCATION

General Recommendations

1. The objectives of the 1967 report of the President's Science Advisory Committee, *Computers in Higher Education*[1] should be met in Minnesota within about five years. This report, commonly referred to as the *Pierce Report* after the chairman of the Committee, called for a nationwide program to bring all college and university computer facilities in the United States up to the level of those best equipped in 1967. Although the *Pierce Report* based its recommendations on the use of time-shared computing to meet all of the instructional needs of higher education, a combination of batch processing and time-shared computing appears more desirable. This is reflected in Section 3 and in the budget recommendations of Section 5 of this report.

2. It is neither necessary nor desirable to establish full-scale educational programs in Computer Science or Data Processing at all public institutions of higher education.

At this time, it appears that the needs of the state will be satisfied by the following well-supported programs:

a) At the University, undergraduate, graduate, and research programs in the Department of Computer, Information, and Control Sciences, plus a strong component of training and research in data processing in the areas of business, educational, and public administration.

b) In the state colleges, about two baccalaureate degree programs with majors in computer science, plus incorporation of computer and data processing training into the programs of all students in science and in business educational, and public administration.

c) One junior college program in data processing, using the administrative computer at Lakewood State Junior College. Some other junior colleges may be able to share in data processing programs at nearby area vocational-technical schools.

d) Six to eight full data processing curricula at area vocational-technical schools. (The use of data processing and computing in other fields, such as accounting, drafting, engineering technology, etc., must be supported in addition.)

Computer installations serving the instruction, training, and administrative needs of higher education must be operated on a service-oriented basis. Where these three functions are combined on one computer, instruction and training should normally be scheduled during the school day, with administrative applications handled at other times.

Regional or statewide computer services which involve several institutions or systems must be organized to provide the users with a meaningful voice in establishing priorities and controlling the level of services provided.

It is clear from conversations with educators and others throughout the state, that regional computing centers and other inter-institutional arrangements will fail utterly if this voice is not provided. The beginning of this process of providing a meaningful policy voice is the development of a charter or statement of mission for the inter-institutional center by the management of the center *and* prospective users.

5. Support is recommended for research and development activities associated with information services and depending on accurate, continuously updated data bases. Such work is being carried out by several groups at the University of Minnesota, in cooperation with various state agencies. This work should receive separate funding – supplemental to the regular operating budgets of the University and of the state agencies involved. Examples of these activities are: the Minnesota Analysis and Planning System (MAPS), the Rapid Analysis Fiscal Tool System (RAFTS), the Land Usage System being developed by the Center for Urban and Regional Affairs and the State Department of Administration, and the Information Management System being developed for the Pollution Control Agency by the Hybrid Laboratory.

The Department of Administration, the University, and the appropriate state agencies should develop a program which includes: (a) a research and development budget for the above systems for presentation to the 1971 Legislature, and (b) a program of orderly transfer of responsibilities to state agencies and departments as the programs move from the developmental to the operational stage.

Appropriations should be made to the appropriate state agencies and contracts should be jointly developed by the University and the agencies for which the University carries out the research and development activities.

Information services planned around archival and bibliographic data bases should be managed by the Statewide Library System mentioned in Recommendation 29.

6. The two systems of higher education which have a defined mission in research and graduate training are the University of Minnesota and, to a lesser extent, the state colleges. Research activities in general are funded by a combination of institutional resources and outside grants and contracts. Research computing is and should be supported in the same way so there is no need for direct funding of such activities as far as these recommendations are concerned. It is necessary, however, that the University have available to it the kind of computer capacity and facilities required for scientific and other research work, and we recommend the maintenance and support of this capacity. If the State Colleges possess enough computing power to accommodate their instructional needs, they should have little difficulty in providing enough excess time to take care of most of their research needs. Certain large computing or data processing problems at the State Colleges may be more economically processed at the University's computer center or eventually at one of the other regional centers. To handle problem interchanges of this kind is one reason for Recommendation 25 that common communications interfaces be maintained between all computers in the state.

7. During the course of this study, it became apparent that there is a serious need for school personnel trained in both educational administration and information and computer technology, as well as for more teachers of business, mathematics, and the natural and social sciences with training in the uses and applications of computers. These needs could be met by adding requirements to existing degree programs and certification standards in order to encourage pre-service training in computer science for teachers and educational administrators. It is recommended that the State Department of Education and institutions granting education degrees adopt such requirements. The major problem in implementing modern information systems and computer instruction technology in local school districts is a lack of people trained in these fields.

Recommendations for Each of the Five Systems of Higher Education

The University of Minnesota

8. The University has already established and is implementing plans to make available to other colleges remote service on its CDC 6600 computer. This external service will be provided within the state on the same cost basis applied to internal users. Funds should be provided for:
   a) Communications controllers and other central site expansion to meet the demand; and
   b) Terminal and communications hardware for colleges within and outside the University which need access to the 6600.

9. The University needs a time-sharing capability to satisfy its own needs; these are currently being met by commercial services. A statewide instructional time-shared computer system should be acquired and established under University management, with sufficient additional capacity to serve, at least for an interim period, the instructional needs of the State Junior College System and the time-sharing needs of nearby private colleges.

10. The University, as the major research institution in the state, should undertake research and development on the applications of CAI, CMI (Computer-Assisted and Computer-Managed Instruction), and other

aspects of learning psychology and technology to the problems of mass higher education. There are potentially large economies and productivity increases in education which may be achieved by these new technologies. However, such applications should be undertaken initially on a research basis because of the high development cost and inherent risk. Appropriate faculty of other state institutions should be involved in these developments so that they may be extended easily for statewide use if proven successful. The Center for Research in Human Learning (CRHL) at the University is concerned with a basic understanding of the teaching-learning process and the application of this knowledge to practical problems of education through CAI, CMI, and other appropriate media. Significant development work is also under way at both Southwest Minnesota State College and Macalester College on the management of instruction by computer. It may be appropriate for the CRHL to play a coordinating role for these activities. But all of them will require some technical services and support.

It is recommended that a statewide center be established and funded to provide computer services and other technical support to development activities in CAI and CMI at the Center for Research in Human Learning *and* at similar centers throughout the State of Minnesota. This Center would also coordinate CAI programs and aid in their transition from research and development to operational or "production" status.

11. Computers have become important instruments in non-computational laboratory instruction, particularly in professional programs in computer science and in engineering. Establishing laboratory computer systems for certain of the University's professional programs in engineering and computer science constitutes an important component for the development of instructional computing in Minnesota. It is recommended that the installation of these laboratory computers at the University be funded.

12. Because of its size, the administrative data processing activity at the University is more complex than that in any of the other systems studied. It is recommended that the University continue to implement an administrative data processing system with complete and well-maintained data bases, as suggested in Section 4. This would prepare a solid foundation for the development of effective management information and program budgeting systems. A study of the University's needs in this area is currently being carried out by Cresap, McCormick and Paget, Inc.

13. Adequate computer services should be supplied to the University's coordinate campuses in the following ways:

    a) Duluth. Its size and distance from other large computer facilities make it uneconomical to supply the Duluth campus with the service it needs over telephone lines. It is recommended, therefore, that the computer capacity at UMD be expanded to keep pace with the level of service required by its students. If after 1975 the regional computer center concept has proven successful, then UMD should be considered as a center for northeastern Minnesota.

    b) Morris. To meet its immediate needs, the Morris campus should be provided with a remote-job-entry terminal to the University 6600. As this campus grows, its capacity may be expanded either by upgrading the terminal to one with some independent computing capability or by providing some terminals to a time-shared computer facility.

    c) Technical Colleges at Crookston and Waseca. The computer needs estimated for these technical colleges most resemble those of a typical junior college. The most effective and economical way to provide them with computer service is via the same mechanism established for the junior colleges; vis., a tie-in to an instructional time-shared computer facility.

The State College System

This recommendation supports, in general, the plan of the State College Board as described in the January 20, 1970 Position Paper by Dr. John E. Haugo[5]. The plan calls for the development of a network of regional computer centers, providing administrative data processing and instructional computing for the colleges, and serving other state and educational (school district) users as well. The first of these regional centers, the southern hub at Mankato State College, is presently in the process of being established. More specific recommendations are as follows:

14. Planning for the northern Regional Computer Center at St. Cloud State College should build on the experience at Mankato, and should proceed in two phases: (1) for installation in 1973 a small-to-medium-sized computer servicing a limited number of remote terminals and operating both independently and as a satellite to the Mankato Regional Center; and (2) a larger independent computer system similar to the one at Mankato, to be installed in 1975. Funding for these phases will be required from the 1971 and 1973 legislative sessions, respectively. The State College Board must request for 1971-72 sufficient funds to develop the staff necessary to plan this center in detail and later to operate it.

15. As soon as possible (i.e., 1970-71), each one of the state colleges excepting Mankato should be provided with remote terminal facilities capable of interfacing with the Mankato Regional Center, with the 6600 at the University of Minnesota, and with any other appropriate facility. The colleges should also be provided with funds for approximately one-half hour per month of computer time and for telephone connections to begin acquiring experience in using large computers, as well as to provide needed immediate services for their students and administration.

16. It is important that the State determine whether a regional computer center serving many different users, as is being established at Mankato State College, is viable. Therefore, it is recommended that the Regional Computer Centers at Mankato and St. Cloud State Colleges be supported in their first few years of operation at a level sufficient to insure that their success or failure results from the level of service they provide rather than from inadequate funding. Users of Regional Center services outside of higher education should be expected to pay for services received; the income should be returned to the State in proportion to the level at which the regional centers are funded. Likewise, since the funding is for instructional purposes, the State Colleges themselves should be expected to pay the regional centers for administrative data processing carried out on these facilities.

17. The development from a two-hub network to a system with regional centers at each of the six state colleges should proceed only after a careful evaluation of the experience during the first five-year period, particularly the experience of users outside higher education. Plans for further expansion of the system to meet the computing needs of higher education should be revised on the basis of this experience.

The State Junior College System

Plans for this system are an extension of current activities and call for separate, centralized facilities – one for administrative data processing and one for instructional computing.

18. For the immediate future, the State Junior College System should continue to have access to an instructional computing system which will provide service to low-speed (teletype) time-shared terminals at each of

the junior colleges, using telephone lines. This service will need to expand from 18 terminals and three computer ports in 1970-71 to about 100 computer ports in 1980-81. It is recommended that the staging of this expansion proceed as follows:

a) 1970. Service from a commercial vendor of time-shared computing (the existing situation).

b) 1971. Service from a time-shared computer dedicated to higher education, and managed by the University of Minnesota or other appropriate agent.

c) 1974-1976. By this time, development in the state should have proceeded to a point at which one of the following three alternative expansion plans can be followed:

   (1) Further development and expansion of the University-managed service. Possibly this would develop into a higher education computer facility independent of the University or other original managing agent with computers at several different locations.

   (2) Establishment of a central instructional computer serving the Junior College System.

   (3) Decentralization of the Junior College System by tie-ins of individual colleges to regional centers. This alternative should *not* be followed unless and until two conditions are met: the regional centers must be capable of providing an adequate quality and quantity of service to the junior colleges they serve; and there must be significant cost savings and/or needed improvements in service to justify and offset the additional problems of articulation and coordination which accompany decentralization of this service within an otherwise centralized system.

19. The centralized administrative data processing system has worked effectively and economically in the past. We recommend continuation of centralized ADP in the Junior College System under the following terms:

a) They should be provided with third-generation data processing facilities, including an efficient COBOL system and increased and expandable disk storage. These facilities could consist of a small-to-medium sized computer system under the control of the State Junior College Board. In this case, the excess computer capacity during off-peak hours should be made available on a reasonable basis to other educational institutions and governmental agencies. Another alternative would be for the junior college data processing staff to work on a large facility controlled by another agency of higher education or state government. The conditions under which this second alternative would be feasible are that the Junior College Board retain its own data processing staff (programmers and system analysts, but not including computer operators) in its employ and under its control; that priority access to the large computer facility be available at least one shift per day and more at peak load periods; and that significant cost savings to the state exist to offset the problems of multiple staffs using a single facility.

b) The data processing staff of the Junior College System should undertake the design of an inexpensive remote inquiry system for the use of administrators at the individual colleges. As programs expand, and particularly at the larger colleges, administrators will encounter needs for quicker access to limited volumes of information on specific students, budget accounts, etc. It should be possible to meet these needs inexpensively through an automatic file query system perhaps using the same low-speed terminals employed for instruction. Development and experimental implementation of this system should begin late in the 1970-75 period, with full statewide implementation occurring during the second five-year period, 1976-80. However, the bulk of the junior college administrative needs can be met effectively and economically as at present, by using delivery services for mass data communications.

Area Vocational-Technical Schools

Plans for these schools are somewhat dependent on the outcome of experiments still under way. Currently three schools have small-scale computers for their data processing and related curricula. Others will have remote-job-entry terminals and at least one will have a mini-computer as a terminal. The planning alternatives thus would appear to be as follows:

a) The centralized system proposed in the ARIES report to the State Department of Education. This alternative is not recommended because it appears to be more expensive than other deployments (see Section 4).

b) A regionalized system whereby those AVTS with computing requirements would have remote batch terminals connected to regional computer centers. This approach should be tried by several AVTS in the very near future in order to determine the viability of this mode of operation for vocational training.

c) Stand-alone computers or mini-computers used as terminals at those AVTS with data processing curricula. Business mini-computers at those schools having very large two-year accounting programs; these mini-computers could also serve as terminals connected to other computers. More limited medium-speed remote-job-entry terminals could be provided at schools with one-year accounting programs.

20. It is recommended that over the next five years alternatives (b) and (c) be implemented at various AVTS to gain experience with their viability for vocational education. This implies the continued support of small (Class G) computers at Alexandria, Hibbing, and perhaps one other location; the provision of six to fourteen business mini-computer terminals (Class i, Table H.7.4) and seven to fourteen simple remote-job-entry terminals (Class k, Table H.7.4), plus the costs of communications and computer service from a state college, the university, or some other public or private agency. At least one of the business mini-computers and one of the simpler terminals should be connected *as soon as possible* to the Mankato regional computer center, so that experience in working with an organization of this kind can be acquired. It is hoped that several of the terminals can work into college or University-based facilities during the five-year period. By the end of this period, it will be possible to make an informed decision on the future direction of facilities for vocational training.

This recommendation does not include the requirements which would be imposed on AVTS computer systems by services to local school districts for either administrative data processing or instructional computing. The instructional computing requirements considered here were primarily those for data processing and other business and trades education within AVTS curricula. Other functions and services would require computer capability in addition to that recommended. (See Section 2 in the Local Government portion of this overall report.)

Private Colleges

The analysis performed in this study has shown that the computer facilities in Minnesota private colleges fall short of their needs. The private colleges represent a valuable educational resource, and it is in the interest of the State of Minnesota to encourage the development of computer facilities and instructional programs in them. The regional centers recommend in this report can surely assist in this.

To support their plans for individual and cooperative uses of computer facilities, the following kinds of assistance to the private colleges are recommended.

21. Technical assistance and advice should be provided by the staffs of the large computer installations in higher education and State government to help the private colleges develop communications interfaces between their terminal and computer hardware and those of the public institutions.

22. Computer systems in the public Institutions should provide services to private colleges at cost. It is specifically recommended that the regional computer centers in higher education provide remote-job-entry service to private colleges with suitable terminals, and that a time-shared computer system used by the University and junior colleges be made available to private colleges who wish to use it.

23. Because of the importance of encouraging the development of computer facilities in private colleges it is proposed that, within constitutional constraints, the State aid development of computing capacity in the private colleges by funding the establishment of regional centers and regional computer communications networks; and by providing grants to the private college to subsidize their use of these services. It is recommended that these subsidy grants build up to cover approximately half the cost of the computer services required to meet the educational needs of the private colleges.

Recommendations Addressed to the Higher Education Coordinating Commission

24. To carry out Its mission to:

> continuously study and analyze all phases and aspects of higher education, both public and private, and develop necessary plans and programs to meet present and future needs of the people of the State in respect thereto, and continuously engage in long-range planning of the needs of higher education and, if necessary, cooperatively engage in such planning with neighboring states and agencies of the Federal government (Minnesota Statutes 136A),

the Minnesota Higher Education Coordinating Commission requires access to machine readable data bases and facilities for processing various kinds of educational data. To honor the requirements of security and privacy, the data bases of the individual systems and institutions should be constructed so that the Commission can gain access to the information needed to carry out its legislative mandates. Similarly, the Commission must be provided with adequate budget support to pay for the data processing needed. At the moment, approximately $17,000/year is being spent on data processing of all kinds but primarily on the Higher Education Facilities Inventory and the Scholarship Program. As these activities are expanded and others added, the Commission must be provided with the additional funding to support the data processing services required by the expansion. With no expansion, a funding level of $20,000/year for data processing would appear to be minimal; the actual needs of the Commission must be assessed by its staff in terms of the programs they are required to support.

The following specific actions are recommended to provide the Higher Education Coordinating Commission with the data processing and information support it needs:

a) Establishment and funding of a full-time staff position to be filled by an analyst with appropriate and extensive training and experience. Although this person would consult with other staff members on applications programs, his primary functions would include analyzing the program needs of the Commission for information and data processing, managing the services required to fill these needs, and advising the Executive Director on program and budget requirements for information and data processing.

b) Access to batch processing services and appropriate data bases at the Computer Services Division, the University, the State

Junior College administrative computer, as appropriate to specific needs. Remote access to these computers and associated data bases may be obtained through the remote terminal of the State College Board, located in the Capitol Square Building. A significant fraction of the use of this terminal may eventually come from the Commission staff.

25. To further enhance the availability and usefulness of information to the Higher Education Coordinating Commission to meet the needs for information on higher education of the legislature, other units of government, and the Federal government, it is important that the data bases of each institution or system either be maintained in a standard format using a standard set of definitions, or that translation programs be provided by the institutions or systems as required to insure comparability of data, both within the state and with other states. It is recommended that the Commission establish a mechanism, involving representatives of the higher education systems and the Commission staff, to develop coordination and security standards for system data bases and application programs. It is expected that this group will maintain cognizance of developing national standards, such as those of the Planning and Management Systems Division of the Western Interstate Commission for Higher Education (WICHE), and will insure that Minnesota is compatible with them when they become nationally accepted.

26. To increase the availability and variety of instructional computer services and to further enhance the availability of information on higher education, a standard communications interface should be established between terminals and computers in all state agencies and Institutions of higher education. It is recommended that the Higher Education Coordinating Commission establish a technical committee, perhaps reporting to the Computer Advisory Committee, to develop the specifications, implementation standards, and coordination mechanisms to create and maintain compatible communications interfaces. This effort should be coordinated with the development of similar standards for State agencies and local governments by having the State Communications Engineer sit on this committee. Since the needs for coordinating computer communications in higher education are immediate, this committee should be formed early in the fall of 1970. It may be possible later on to form a single data communications standards committee serving all governmental agencies, including higher education.

27. The M[illegible]esota and North Dakota Higher Education Commissions are in contact conce[illegible] exchanges of students and other topic[illegible] Because there are geographical affinitie[illegible] between eastern North Dakota and northw[illegible]rn Minnesota, it is recommended tha[illegible] Minnesota Higher Education Coor[illegible] Commission explore with its North [illegible] counterpart arrangements for sharin[illegible] the use of computer resources. A logic[illegible] step in this direction would be for [illegible]sota to invite a technical r[illegible]tive from North Dakota to par[illegible]te in the work of the Co[illegible]ion Standards Technical Comm[illegible] it is the work of this committee which will be instrumental in the sharing of computer resources both within and without the State.

28. A great need exists for in-service computer and information systems training for educational administrators and secondary mathematics and science teachers. In-service training opportunities should be provided throughout the state through the continuing education services of the University, the State Colleges, and the school districts. Many excellent in-service programs have been offered through these systems, but they seem to be offered with little consultation among the institutions with missions involving this

kind of public service and with little geographical coordination. To provide the needed channels of communication and coordination, we recommend the establishment by the Commission of an *ad hoc* Committee on the Coordination and Standards of Pre-Service and In-Service Training Programs in Computing and Data Processing.

29. The Minnesota Higher Education Coordinating Commission, or some other appropriate agency, should act to initiate the planning for and development of a Statewide Automated Library System. The organization envisioned for this System will probably be managed by an Executive Officer acting under the direction of a Policy Board representing the several kinds of libraries in the state and advised on technical matters by a Technical Advisory Board. It is recommended that the Commission establish these boards immediately, and charge them with preparing for the 1971 Legislature a detailed implementation plan based on the work of the University Library Systems Staff and the Becker and Hayes evaluation and recommendations (Appendix H.2). This plan must include a specific designation of the organizational structure and staffing required to administer development of a Statewide Automated Library System. Being an organization involving a large geographical area (the entire state) and a wide variety of libraries with differing missions, the concerns expressed under Recommendation 4 above are relevant here.

30. The effective use of computers in higher education will continue to require developmental efforts by specialists versed in higher education and computer technology. The special appropriation of $300,000 by the 1969 Legislature has been most effective in stimulating the development of many useful computer applications and services in higher education. It is recommended that:

    a) The computer Advisory Committee of the higher Education Coordinating Commission prepare for the 1971 Legislature a report summarizing and evaluating what has been accomplished with these funds over the time they have been available; and

    b) Limited and special developmental efforts continue to be funded through an appropriation to the Commission in a manner similar to the interim funding of 1969-71, and at a similar or slightly expanded level.

To distribute these funds in the most effective manner, the Commission should establish a review panel to evaluate proposals and recommend funding, as was done with the special appropriation for the 1969-71 biennium.

The links between institutions and systems implied by the preceding recommendations will require a high degree of coordination in developing the facilities and organizations required to achieve an effective and efficient educational computing capacity in the state. To bring about this coordination, the Minnesota Higher Education Coordinating Commission has based its approval of this Report on the following statements of general policy:

1. All institutions and systems of higher education, prior to the development of their legislative requests, shall identify to the Higher Education Coordinating Commission their plans for computing for both facilities and for operating costs. These plans should provide detailed information on budgeted costs and program justification. The Commission shall review these proposals to determine how these plans are coordinated with the Master Plan – how they approximate the goals and where they deviate from them. The Commission shall prepare a Summary Report for each Legislature on the progress that has been made toward achieving the goals of the Master Plan. This Summary Report also shall include recommendations regarding the requests which are being submitted by the institutions and systems, and by the Commission itself.

2. For on-going or operational computing activities, the responsibility for planning and for preparing legislative requests shall rest with the individual systems of higher education. Funding will be appropriated to the individual systems.

3. The Computers and Information Systems in Higher Education Report identifies four programmatic areas of a developmental nature. These are:

   (a) a development center for Computer-Assisted and Computer-Managed Instruction.

   (b) a State-wide automated library system.

   (c) a program of grants for projects in research and in development, within each biennium, related to computing in higher education (continuation of an existing program).

   (d) grants to private colleges in support of their computing activities.

   For these four developmental activities, the responsibility for planning shall rest with the Commission. For grants programs (c and d above) the Commission will also prepare the legislative requests and receive the appropriations. For activities which involve both new facilities and operating support (a and b above), the legislative requests will be prepared jointly by the Commission and those individual systems which plan to make use of the facilities. Appropriations for facilities will be made to the Commission; appropriations for operating costs associated with the developmental activities themselves will be made to the appropriate system or agency, including the Commission itself. The Commission may assign management responsibility for the facility to another board or agency.

4. Adjustments in implementation plans presented to the legislature in accordance with procedures outlined in Number 1 above shall be subject to review by the Commission.

5. The Commission proposes to review periodically the effectiveness of the policies being adopted here and to make or recommend such changes as it deems advisable.

Adopted by the Executive Committee
of the Minnesota Higher Education
Coordinating Commission
September 17, 1970

A TIME-PHASED FIVE-YEAR PLAN

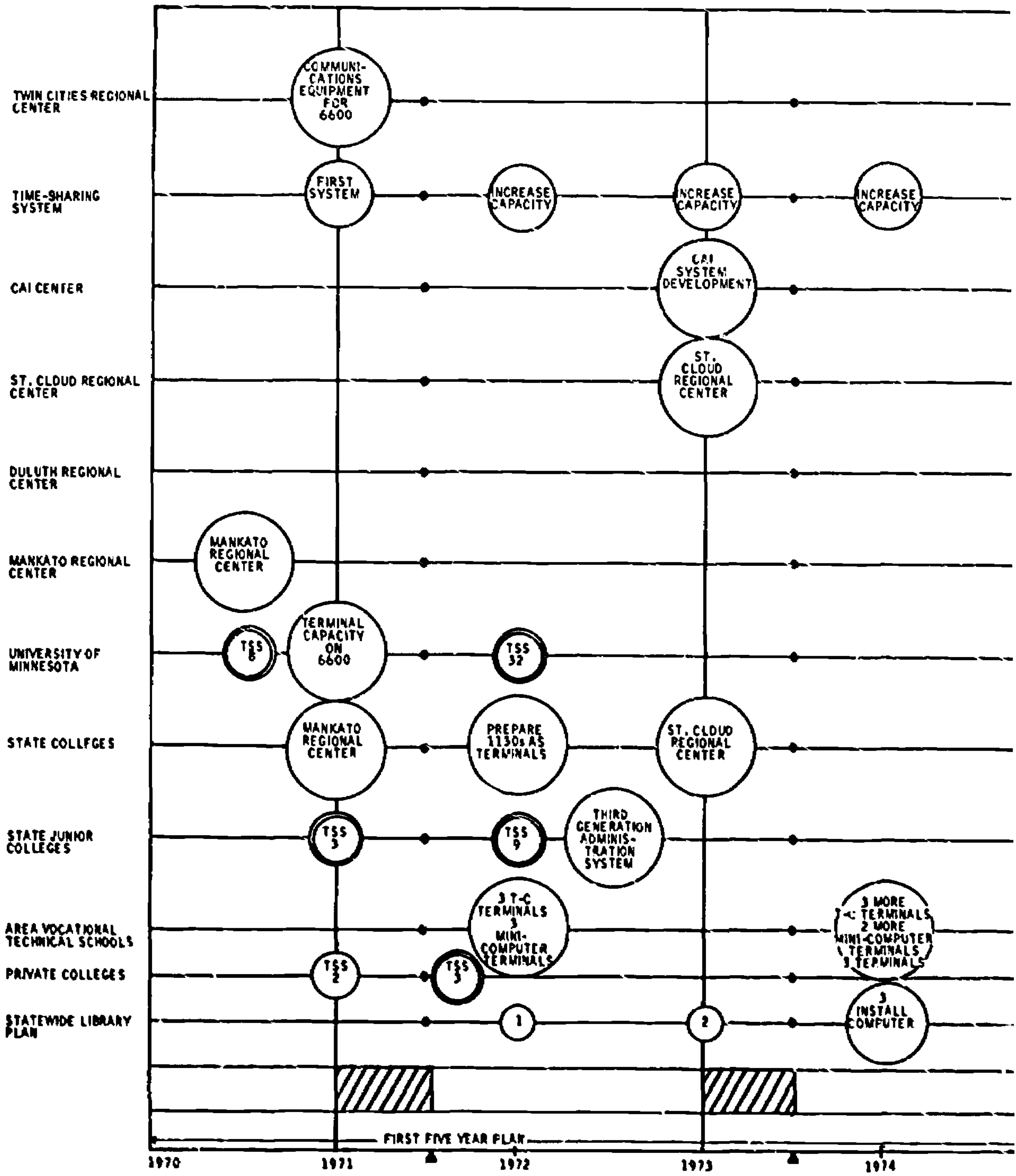
Figure 5.1 displays a long-range plan for computers and information systems in public and private higher education in Minnesota. Planning for the first five years is naturally much more specific and detailed in this chart than for the second five years. The plan is further detailed as an estimated budget in Tables 5.1 through 5.5. All cost projections, in these and other tables in this report, are based on uninflated 1970 dollars, and on enrollment projections for 1974 or 1975 obtained during the spring and early summer of 1970 from the systems of higher education or through the Higher Education Coordinating Commission. If significant monetary inflation occurs, or if the enrollment goals or projections of institutions change from those represented in Appendix H.10, then appropriate adjustments must be made in the budget projections of Tables 5.1 through 5.5.

Table 5.1 lists existing computing facilities by function and includes estimates of equivalent net purchase price; equivalent annual lease price (estimated at 27% of the purchase price); and recommended annual support budgets which are estimated here as well as in Tables 5.4 and 5.5 as follows:

- For administrative data processing facilities, 2.0 times the annual lease including maintenance, or 60% of purchase price per year.
- For facilities combining administrative and education computing, 1.5 times the annual lease including maintenance (45% of purchase price per year).
- For instructional computing facilities, 1.0 times the annual lease including maintenance (30% of purchase price per year).
- For time-sharing central computer facilities, 0.6 times the annual lease including maintenance.
- For remote terminals, 0.5 times annual lease (medium-speed) or 0.1 times annual lease (low-speed or time-sharing), both including maintenance.

The actual support budgets for existing facilities are also given if they are known. Table 5.2 gives a proposed funding schedule for computing equipment for 1971-1975 on a purchase basis. This funding schedule for the next two legislative biennia estimates the costs of the recommendations in the previous section. These recommendations encourage the development of major regional computer centers at the University, at Mankato State College, at St. Cloud State College, and eventually at Duluth. Costs of equipment for a time-sharing system and the vocational schools are also significant. The equipment cost listed for the Statewide Library Plan would be the computer to be acquired during the third phase of that plan. Table 5.3 presents the same information as Table 5.2 but on a lease basis rather than a purchase basis. The factor 0.27 was used in computing lease equivalents because maintenance was assumed to be a part of operating costs and is included in Tables 5.4 and 5.5. The spending levels for facilities do not show a notable increase over 1964-1969 levels during the first year of the plan (1970-1971) since funding for that year has already been allocated, but they do increase markedly beginning with the second year (see Figure 5.2).

Operating costs corresponding to the new equipment are estimated in Table 5.4 as an incremental budget forecast. The same information is given in Table 5.5 in the form of total rather than incremental yearly costs. These budgets for equipment and operations should not be interpreted as refined estimates of planned expenditures, but they do serve to evaluate the costs of the fundamental recommendations, i.e., attempting to meet *Pierce Report* goals by 1975[1].



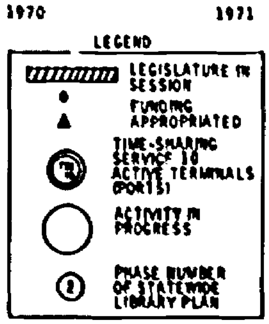
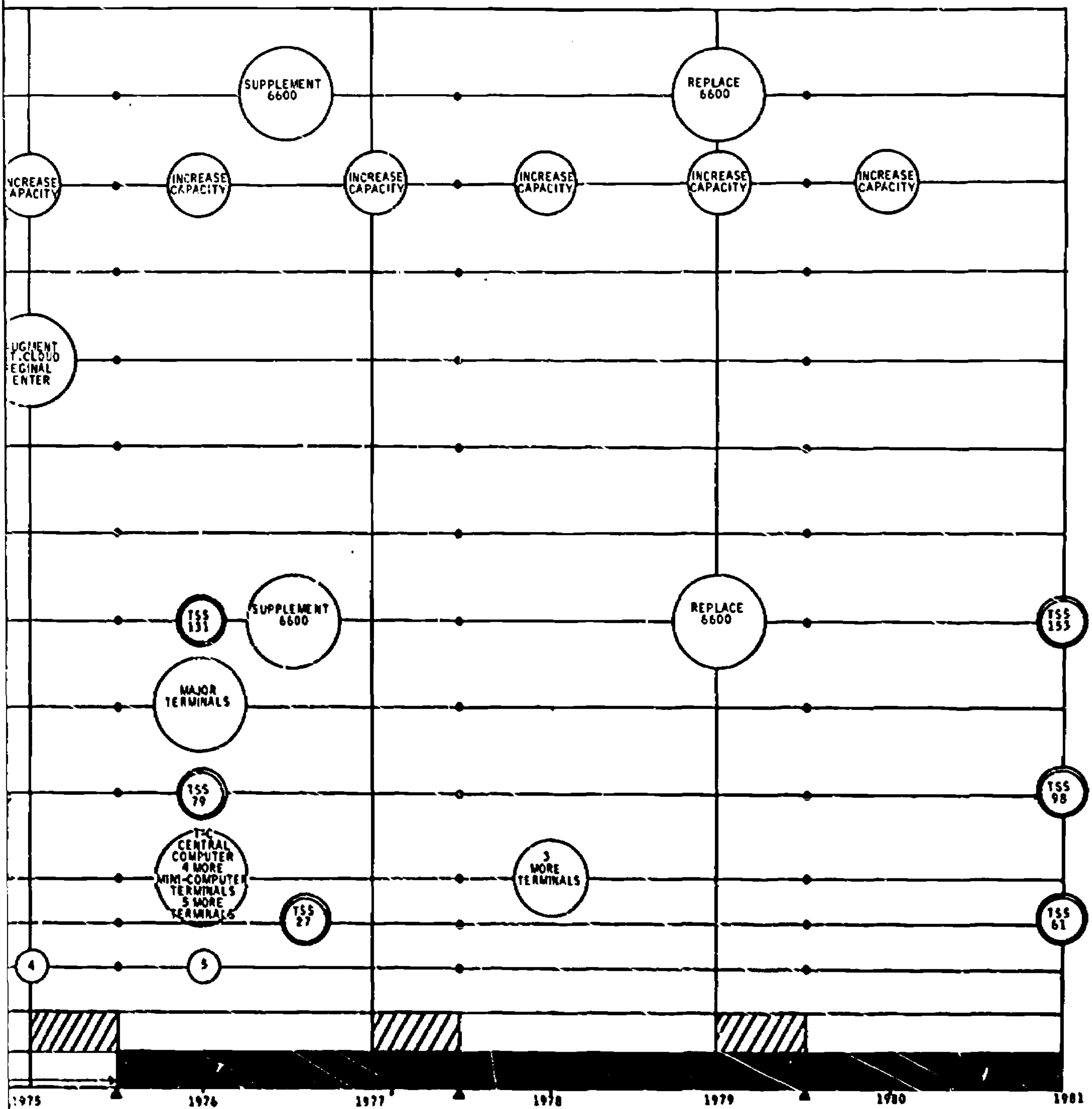


Figure 5.1. Statewi



lan for Computers in Higher Education

During the latter stages of preparing this report, it became apparent that two of the cost and capacity standards used in this section and in Section 4 were no longer accurate:

- The standard medium-speed remote job entry terminal (Class k in Table H.7.4) will not operate at 300 lines or cards per minute, but more nearly at 150 lines or cards per minute. The one terminal which performs at the higher rate and sells near the $32,000 purchase cost of a Class k terminal has been removed from production (except in Japan), and is no longer readily available. Correcting the cost estimates in Sections 4 and 5 to account for this would require a doubling of the number of medium-speed terminals, or stepping up their cost and capacity to Class j, either of which would approximately double the estimated cost. In addition, extra communication line capacity would be needed.
- The Bell Telephone System has just announced an originate-only low-speed modem, which reduces the lease cost of a teletype terminal (Class m) from $75 to $62 – about 17%.

The numbers and costs of terminals estimated here and in Section 4 have not been changed to reflect these conditions because of the time pressure on completion of this report and also for three more valid reasons: (1) the increase in costs associated with Tables 5.1-5.5 and the summary table under Plans in Perspective range from about 2% of the total in 1971-72 to 7% in 1974-75, well within the accuracy which can be claimed for any of these estimates; (2) changes in technology and pricing are most likely to be substantially greater than this by 1975, invalidating even these corrections to the cost estimates; and (3) it is possible, and even educationally desirable in some cases, to use one high-speed remote terminal to replace five or six medium-speed terminals when communication line costs are not a significant factor, thus reducing terminal costs somewhat. It is most important that those using this report for planning and evaluation make note of these current inaccuracies, so that discrepancies of a factor of two in the terminal numbers and costs quoted in Tables 4.1-4.3, 4.6, 5.2, and 5.3 will not come as a complete surprise. These changes also illustrate the fact that estimates of the kind developed in this report must be consistently updated and modified – they are never precise. However, the changes are a small fraction of total costs, and except for the effects of inflation, we would expect them to tend downward rather than upward.

Not only do the expenditure schedules in Tables 5.2 through 5.5 represent the recommendations of this study – they also approximate reasonably the projections of those systems of higher education which have developed plans. Although the schedules appear to disagree with the plans of the State College System[5] which call for installation of a second Class D or E Regional Computer Center late in the 1971-73 biennium, the real difference is in the allocation of funds rather than in accomplishing the objectives of this center on schedule. Installation of a much smaller Class F or G satellite computer in 1972-73 will permit St. Cloud State College to develop the staff and faculty expertise to effectively utilize a large computing center; it will provide adequate services to surrounding school districts which, as observed during the course of this study, are anxious to obtain access to services of this kind; and higher education will not be encumbered with the costly excess of computer capacity accompanying a large center installed prematurely. By the time a decision is needed to go ahead with the expansion scheduled for St. Cloud in 1974-75, it will be possible for the State College Board to make a more informed decision on how to proceed, based on experience with the large center in Mankato and the smaller satellite center in St. Cloud.

A SECOND FIVE-YEAR PLAN

Changes in technology and its influence on higher education tend to make a prediction for ten years ahead somewhat difficult with any degree of confidence. If the plan of the first five years

Table 5.1. Existing Computing Facilities in Public Higher Education by Function, 1970-71 (Including Those Approved for Acquisition)

Facility	Purchase Price(c)	Equivalent Annual Lease (0.27 of Purchase Price)	Recommended Support Budget(a) for Instruction and Administration	Actual Budget Support for Instruction and Administration
SYSTEMS AVAILABLE FOR STATEWIDE USE:				
6600 System[b]	$2,560,000[c]	$ 693,900	$ 388,500[c]	$ 227,000
Mankato Regional Center[e][m]	1,200,000	200,000[m]	285,000[m]	200,000
UNIVERSITY				
West Bank 3200[e]	450,000	121,500	135,000	37,000
Duluth 3200[c]	440,000	118,800	132,000	98,000
Administrative System 360/50	1,500,000	405,000	900,000	688,000
Hybrid Computer[b]	580,000	156,600	52,000	42,000
Time-Sharing from Commercial Vendors	60,000	(60,000)[e]	(f)	(f)
Health Sciences 3300[b]	825,000	222,750	25,000[b]	25,000
STATE COLLEGES				
Small Computers (Instruction and Administration)	967,000	235,000	392,000	325,000
STATE JUNIOR COLLEGES				
Administrative System 1401	163,000	(44,010)	97,800	53,000
HECC FUNDED PROJECTS	253,700[a]	(40,500)	60,000	
State College Projects				
Junior College Time-Sharing Project				
Campus Management Simulation				
AREA VOCATIONAL-TECHNICAL SCHOOLS				
Alexandria HW200	221,000	59,670	33,150[k]	Not Available or Relevant
Mankato 360/25	233,000	62,910	34,950[k]	
Hibbing HW200	232,000	62,640	34,800[k]	
Moorhead	40,000	10,800	2,400[k]	
Willmar	40,000	10,800	2,400[k]	
TOTALS	$9,764,700	$2,360,370	$2,575,000	$1,695,000

(a) The recommended annual support budget is based on 30% of the market value of computer hardware, times the percent instructional and administrative use of the system (assumed 100% unless otherwise mentioned), times a factor of 2 for administrative computers; 1.5 for systems supporting both instruction and administration; 1 for instructional computers and associated hardware; 0.5 for medium-speed remote terminals; and 0.1 for low-speed (teletype) terminals.

(b) These systems are used both for instruction and for research. In Table 5.4, the operating budgets are for instructional usage only. For 1970-71, the instruction versus research usage will be approximately as follows: (a) 6600, 35% and 65%; (b) 3300, 10% and 90%; (c) Hybrid, 30% and 70%.

(c) The market value of the computer equipment listed here is approximately equal to the purchase price, except for the University's 6600, which has a market value of about $3.7 million. It is on market value that recommended support budgets are based.

(e) For planning purposes, these systems are assumed to be 100% instructional.

(f) Included in equivalent annual lease.

(g) For both hardware and support.

(h) Because a large amount of applications programming is required by funded research users, the Health Sciences computer must be supported at the 2:1 ratio characteristic of administrative processing.

(k) For reasons discussed in Table 4.5, support for vocational school facilities has been figured at 50% of equivalent annual lease plus maintenance for computers, and 20% of this for terminals.

(m) Installed at mid-year, so costs are for six-month period.

(l) Not included in the total, because these expenditures are superseded in Tables 5.3 or 5.5. All other costs in this column remain to be added to Table 5.3 in arriving at total annual facility support.

Table 5.2. Proposed Funding Schedule for Computing Equipment 1971-75 (Purchase Basis, 1970 Dollars)

Facility	1971-72	1972-73	1973-74	1974-75
SYSTEMS AVAILABLE FOR STATEWIDE USE:				
6600 System				
Peripheral Equipment for Remote Terminals	230,000			
Time-Sharing System	240,000	240,000	240,000	240,000
CAI Center	275,000		300,000	
Mankato Regional Center				
St. Cloud Regional Computer		320,000		1,200,000
Duluth Regional Computer	55,000 (Core Expansion)		55,000 (Core Expansion)	
UNIVERSITY				
Administrative Computer System		70,000 (Disc Expansion)		
3200 Core Expansion (West Bank)		55,000		55,000
Special Lab Computers	300,000	300,000	300,000	350,000
Supplement to Health Sciences and Hybrid Instructional Facilities			150,000	
Terminals to 6600	175,000	175,000	175,000	200,000
Terminals to Time-Sharing System	72,000	72,000	72,000	72,000
STATE COLLEGES				
Terminals to Regional Centers	150,000	30,000	150,000	150,000
STATE JUNIOR COLLEGES				
Terminals to Time-Shared Computer System	46,800	33,200	34,000	33,600
Administrative Computer		270,000		
AREA VOCATIONAL-TECHNICAL SCHOOLS				
Terminals	370,000	370,000	408,000	425,000
[redacted]				
STATEWIDE LIBRARY SYSTEM			1,470,000	

Table 5.3. Proposed Funding Schedule for Computing Equipment to be Added During 1971-75 (Lease Basis; Annual Lease = 27% of Purchase Price, in 1970 Dollars)

Facility	1971-72	1972-73	1973-74	1974-75
SYSTEMS AVAILABLE FOR STATEWIDE USE:				
6600 System				
Peripheral Equipment for Remote Terminals	62,100	62,100	62,100	62,100
Time-Sharing System	65,000	130,000	195,000	260,000
CAI Center	74,250	74,250	155,250	155,250
Mankato Regional Center				
St. Cloud Regional Computer	-	96,000	96,000	324,000
Duluth Regional Computer	14,850	14,850	29,700	29,700
UNIVERSITY				
Administrative Computer System	-	19,000	19,000	19,000
3200 Core Expansion (West Bank)	-	14,850	14,850	29,700
Special Lab Computers	81,000	162,000	243,000	347,500
Supplement to Health Sciences and Hybrid Instructional Facilities	-	-	40,500	40,500
Terminals to 6600	48,000	96,000	144,000	198,000
Terminals to Time-Sharing System	36,000	72,000	108,000	144,000
STATE COLLEGES				
Terminals to Regional Centers	40,500	48,600	89,100	129,600
STATE JUNIOR COLLEGES				
Terminals to Time-Sharing System	(26) 23,400	40,000	57,000	(82) 73,800
Administrative Computer	44,000	73,000	73,000	73,000
AREA VOCATIONAL-TECHNICAL SCHOOLS				
Terminals	100,000	200,000	310,000	425,000
TOTALS	589,100	1,102,650	1,636,500	2,311,150
STATEWIDE LIBRARY SYSTEM			396,000	396,000

Table 5.4. Approximate Annual Incremental Operating Budget Needs (1970 Dollars)

Facility	Funding Level for 1970-71	Annual Budgets (Increments)			
		1971-72	1972-73	1973-74	1974-75
SYSTEMS AVAILABLE FOR STATEWIDE USE					
6600 System					
Peripheral Equipment for Remote Terminals		34,000	0	0	0
Time-Sharing System	(c)	43,300	43,300	43,300	43,300
CAI Center		40,000	40,000	45,000	45,000
Mankato Regional Center[(a)]	200,000	160,000	0	0	0
St. Cloud Regional Computer[(a)]	-	-	53,000	53,000	127,000
Duluth Regional Computer	98,000	16,000	16,000	17,000	18,000
UNIVERSITY					
Administrative Computer	688,000	62,000	60,000	60,000	50,000
Instructional Usage of Existing Instruction and Research Facilities	331,000	220,000	70,000	70,000	71,000
Facilities Expansion					
Remote Terminals to 6600		26,200	26,200	26,200	30,000
Time-Shared Terminals		4,000	4,000	4,000	4,000
3200 Expansion (West Bank)			16,500		33,000
Health Science and Hybrid		-	-	22,500	22,500
STATE COLLEGES					
Small Computers	325,000	0	-25,000	-25,000	-43,000
Remote Terminals		22,500	4,500	22,500	22,500
STATE JUNIOR COLLEGES					
Time-Shared Terminals	(c)	2,600	1,800	1,900	1,900
Administrative Computer	53,000	12,000	15,000	25,000	40,000
AREA VOCATIONAL-TECHNICAL SCHOOLS		20,000	20,000	21,000	21,500
Communications Leasing and Line Costs	19,000[(b)(c)]	81,000	100,000	100,000	72,000
HECC Funded Projects	150,000	25,000	-	25,000	-
Private College Usage Fund		35,000	35,000	35,000	35,000
Total Incremental Operating Budgets	$1,864,000	$803,600	$ 480,300	$546,400	$540,700
STATEWIDE LIBRARY SYSTEM		931,400	1,258,100	489,000	693,400

[(a)] See footnote a, Table 5.1, for basis on which operating budgets were developed.

[(b)] Includes high-speed data links at University plus time-shared terminal communications cost at the University.

[(c)] These costs for the Junior College time-shared network are included as part of HECC-funded projects. They amount to about $15,000 (service., $12,000 (terminals) and $12,000 (communications) for the year.

Table 5.5. Approximate Annual Total Operating Budget Needs (1970 Dollars)

Facility	Funding Level for 1970-71	1971-72	Annual Budgets (Total Costs) 1972-73	1973-74	1974-75
SYSTEMS AVAILABLE FOR STATEWIDE USE:					
6600 System					
Peripheral Equipment for Remote Terminals		34,000	34,000	34,000	34,000
Time-Sharing System	(c)	43,300	86,600	129,900	173,200
CAI Center		40,000	80,000	125,000	170,000
Mankato Regional Center	200,000	360,000	360,000	360,000	360,000
St. Cloud Regional Computer		-	53,000	106,000	233,000
Duluth Regional Computer	98,000	114,000	130,000	147,000	165,000
UNIVERSITY					
Administrative Computer	688,000	750,000	810,000	870,000	920,000
Instructional Usage of Existing Instruction and Research Facilities	331,000	551,000	621,000	691,000	762,000
Facilities Expansion					
Remote Terminals to 6600		26,200	52,400	78,600	108,600
Time-Shared Terminals		4,000	8,000	12,000	16,000
3200 Expansion		16,500	33,000	66,000	99,000
Health Science and Hybrid		-	-	22,500	45,000
STATE COLLEGES					
Small Computers	325,000	325,000	300,000	275,000	232,000
Remote Terminals		22,500	27,000	49,500	72,000
STATE JUNIOR COLLEGES					
Time-Shared Terminals	(c)	2,600	4,400	6,300	8,200
Administrative Computer	53,000	65,000	80,000	105,000	145,000
AREA VOCATIONAL-TECHNICAL SCHOOLS		20,000	40,000	61,000	82,500
Communications Leasing and Line Costs	19,000[b][c]	100,000	200,000	300,000	372,000
HECC Funded Projects	150,000	175,000	175,000	200,000	200,000
Private College Usage Fund	-	35,000	70,000	105,000	140,000
Total Operating Budgets	$1,864,000	$2,684,100	$3,164,400	$3,753,800	$4,337,500
STATEWIDE LIBRARY SYSTEM		931,400	2,189,500	2,678,000	3,371,400

[a] See footnote a, Table 5.1, for basis on which operating budgets were developed.

[b] Includes high-speed data links at University plus time-shared terminal communications cost at the University.

[c] These costs for the Junior College time-shared network are included as part of HECC-funded projects. They amount to about $15,000 (service), $12,000 (terminals) and $12,000 (communications) for the year.

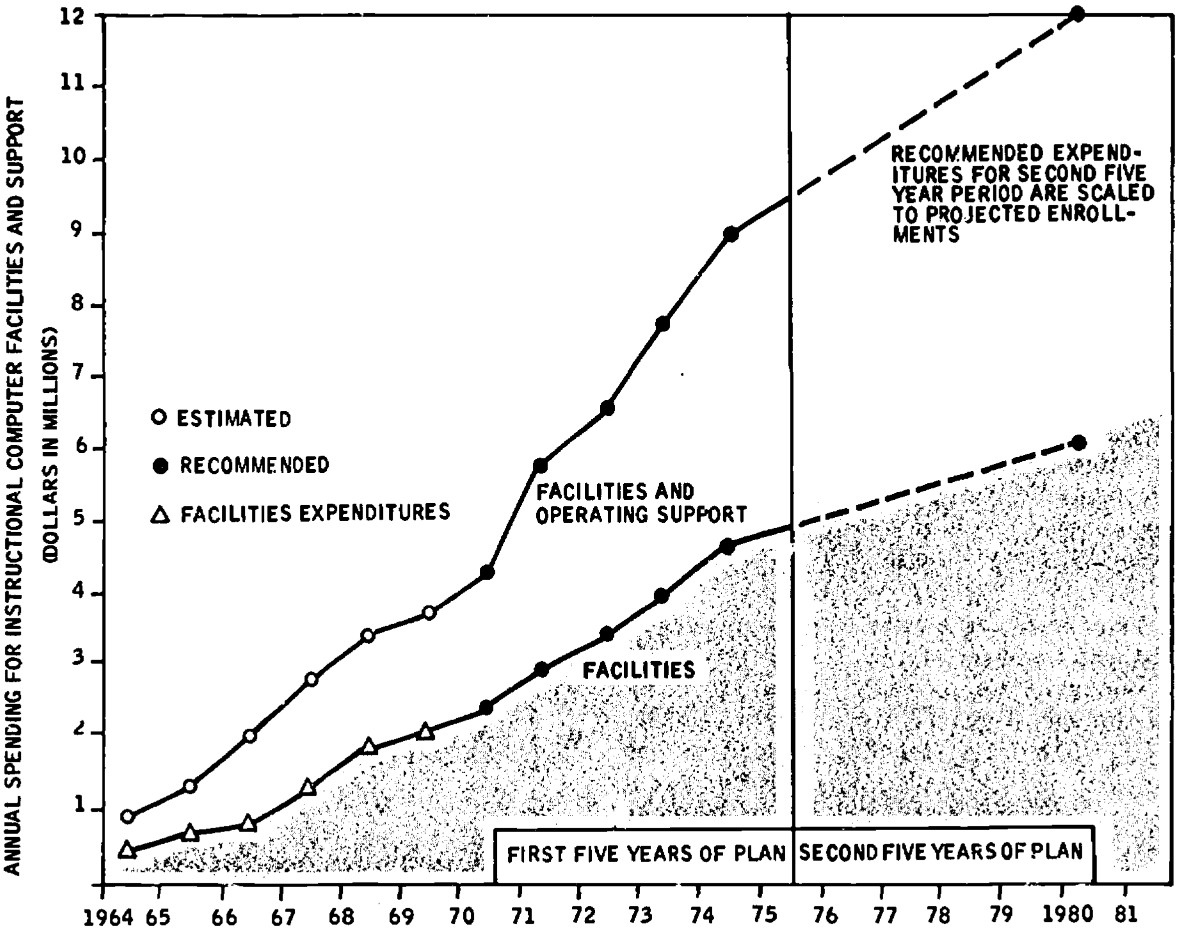


Figure 5.2. Public Funding for Computers in Minnesota Higher Education

succeeds in giving all post-secondary students in Minnesota access to computer facilities in the same degree that, say, Dartmouth College students had in 1967-68, then much will have been achieved. Changes in technology, by 1976 may, however, require that a larger segment of the student population have substantial rather than casual or limited exposure to the computer. Such a shift would tend to require more equipment in 1976-81 than is indicated in Figure 5.1, since most of the increases shown there merely reflect increase of student population and replacement or augmentation of aging computers. Before detailed planning for the second five years begins, the regional center approach must be thoroughly evaluated.

A major factor in the second five years would be the decision to expand the regional computer centers in the state colleges to all six colleges. This will depend on the mission and success of these centers and a growth of demand in outstate areas which is difficult to predict at this time. Thus, Figure 5.1 does not prejudice the outcome of the review called for in 1975 by the recommendations.

It is possible to make some general predictions with a certain degree of confidence. The growth of instructional and research computing at the University will almost certainly overload the CDC 6600 by 1976 (Appendix H.4). Thus, it will be necessary to supplement the system by a foreground computer (for example a 6400 to upgrade to a 6700 configuration). This augmentation will probably provide only temporary relief, and a replacement system is indicated in Figure 5.1 in 1979. At that time it may be technically possible to subsume the time-sharing system into the larger facility, but it is difficult now to see what time-sharing will become when it matures. The Area Vocational-Technical Schools are experimenting with terminals. If these experiments are successful and if more data processing programs are started in the Twin Cities area, then by 1976 there will probably be enough utilization to justify a central vocational school facility in the Twin Cities.

During the short history of computer development and application, it has consistently been the case that predictions of growth over one or two years have been too optimistic, yet predictions over five to ten years have been much too pessimistic. It is not unlikely that the forecasts of demand for instructional computing given in this report will follow this tradition

THE PLANS IN PERSPECTIVE

The *Pierce Report*[1] called for a nationwide expenditure by 1972 of $414 million per year for instructional computing alone in order to bring all college computer facilities and programs up to the quality of those colleges which were well-equipped in 1967. Minnesota's proportionate share would be about one-fiftieth of this amount, $8.3 million. Adding together the annual facilities costs in Tables 5.1 and 5.3, and their corresponding support costs estimated in Table 5.5, gives the following approximate annual costs of the proposed Minnesota plan:

ANNUAL COST DATA

Academic Year	Facilities	Support	Total
1970-71	2,360,000	1,864,000	4,224,000
1971-72	2,949,000	2,864,000	5,813,000
1972-73	3,463,000	3,164,000	6,627,000
1973-74	3,997,000	3,754,000	7,751,000
1974-75	4,672,000	4,338,000	9,010,000

When it is recognized that the costs of this plan include administrative data processing, a significant research and public service capacity at the University, and substantial excess capacity for these and other applications at the state colleges, then the cost of the proposed plan is no greater, and perhaps less, than the President's Science Advisory Committee suggested through the *Pierce Report* in 1967.

The proposed expenditures for 1970-75 are shown graphically in Figure 5.2, bracketed by estimated expenditures during the previous six years and projected costs for 1975-80. The two features of these graphs which are most conspicuous are the leveling off in expenditures for computing in higher education during the 1968-70 period, and the increased rate of funding recommended for 1971-75, which compensates for the reduced growth rate during the previous few years. After 1975, the growth rate projected is strictly proportional to enrollment and does not allow for any inflation of the 1970 dollar.

Although the total cost per year of these recommendations in 1975 is certainly formidable, it does not appear quite so staggering on a per-student basis. Assuming about 160,000 students in public institutions in 1974-75, the cost of computing averages to about $56 per student per year. This compares with $60 per student per year estimated for achieving similar levels of instructional computing in the *Pierce Report*[1]. The same report related this to two other functional costs of higher education. College and university libraries, an instructional resource which is generally available to students and faculty in the same way the Pierce Committee wanted computers to be available, cost between $50 and $200 per student per year in 1966. And chemistry laboratory instruction costs about $95 per year per chemistry student. On this basis, the costs proposed in this report appear reasonable.

Cost per student per year in the four public systems of higher education in Minnesota are estimated in Table 5.6. These have been derived from Table 4.5 rather than the tables in this section because that table more readily reflects the cost for general instructional computing and administrative processing in each of the systems, and does not include the excess capacity for research and public service. Hence, the cost-per-student figures in Table 5.6 are estimates of actual student-related expenditures. The relatively high cost of computing at the University is an accurate reflection of the high cost of graduate and post-graduate professional training in general, the bulk of which is concentrated at the University. The lower cost of computing in the state colleges is partially a result of the fact that, since they have no separate administrative computer, it has been assumed that their administrative work is accommodated on the third shift of the instructional capacity they use. No extra cost has been incurred in Table 4.5 for state college administrative processing (except for mass storage) in contrast to the other two collegiate systems. In practice, this assumption is somewhat unrealistic; there will be some additional staff and operating support costs and these are reflected in Tables 5.1, 5.4, and 5.5.

The overall cost-per-student in the vocational-technical schools is not much different from the other institutions. But when it is recalled that most of the computing there is done by data processing students and most of the rest by students in accounting, the story changes. However, even these high costs are not unreasonable when placed in perspective. The vocational schools are the only post-secondary institutions with adequate program cost data. Computer facilities account for about one-half of the cost of training students in data processing, with faculty accounting for most of the other half – a 1:1 hardware-to-staff ratio (recall that staff was not included for vocational schools in Table 4.5). This gives an approximate program cost of $1,300 per student per year. Two entirely independent estimates of this cost during visits to two Area Vocational-Technical Schools resulted in figures of about $1,200 per student per year. This is about the same as the cost of training a machinist, and somewhat less expensive than training a welder. The situation would be rather similar for computer science and certain engineering students at the University. If Minnesota wishes to provide this kind of education, the costs must be borne. Such estimates also point up the desirability of program budgeting, so that decisions about programs can be made on a more informed basis.

Table 5.6. Annual Cost Per Student of the Computing Capacity Proposed for Minnesota Higher Education in 1975, in 1970 Dollars (Derived from Table 4.5)

System	Approximate Total Monthly Cost of Computing in 1975	Approximate Total Annual Cost of Computing in 1975	Approximate Total Enrollment in 1975	Approximate Annual Cost of Computing Student in 1975
University	$340,000	$4,100,000	61,000	$ 67
State Colleges	172,000	2,100,000	54,000	39
Junior Colleges	69,000	828,000	27,000	31
Area Vocational-Technical Schools	65,000	780,000	19,000	41
Data Processing		600,000	900	667
Accounting		180,000	1,200	150
TOTALS	$646,000	$7,808,000	161,000	$ 48

Finally, the total operating costs of public higher education in Minnesota in 1974-75 are estimated at about $370 million[11]. The cost of achieving the level of computing proposed here will amount to about 2.5% of this total operating cost. Again, this compares conservatively with the estimate by the Pierce Report in 1967, that achieving their goals for general instructional computing would consume about 4% of the annual cost of higher education.

If the State of Minnesota desires to achieve the goals set forth here for computing in higher education, funding must come from state sources for the near future at least. The Federal budget situation and the current recession affecting the computer industry do not auger well for Federal grants or substantial manufacturers' discounts. Despite the pessimistic outlook, higher education must do everything it can to tap these outside resources, which implies in turn that enough flexibility must be built into funding and coordinating mechanisms to provide matching funds when they are needed. The outlook for outside funding cannot get much worse; it could improve considerably during the next several years. But in either case, we believe that tangible evidence of a commitment by Minnesota higher education and the Legislature to coordinated planning guidelines, such as represented by this report, will significantly improve the changes of obtaining outside resources to implement the plans.

PRIORITIES

Despite the evidence that the proposed plan is not an unreasonable expense for higher education, its total cost by 1975 is clearly high enough to cause concern by the Minnesota taxpayer and his elected representatives. It may not be possible to achieve the desired level of computing capacity by 1975 – aiming at that level for 1980 would, in fact, distribute the rate of increase of spending more uniformly (see Figure 5.2). If support cannot be provided at the level suggested, then it is recommended that priorities for spending available funds should be as follows:

1. Support for existing facilities, especially the statewide or regional facilities at the University of Minnesota and Mankato State College.
2. Establishment of a limited-capacity statewide time-shared computer facility to provide service at slightly above present levels to the junior colleges, the University, and the private colleges which wish to use

it. This is the only kind of instructional computer service presently economical for and useful at the junior colleges.

3. Support for establishment of a statewide center to support development work on computer-assisted and computer-managed instruction. The potentials for economies and effectiveness of this development are too great to ignore.

This minimal increment would amount to about $900,000 for 1971-72, as compared with $1.4 million indicated for the recommended plan.

But it is properly the responsibility of higher education itself to set these and other priorities, either within institutions and systems as in the past, or through the Minnesota Higher Education Coordinating Commission as recommended in this report. Priorities for computing cannot be established independently of other demands for services, faculty, equipment and supplies, and buildings, nor independently of the programs which exist in the several institutions and which may require computing or other support for their existence. This report may serve as a useful planning guideline, but it is the people within higher education – faculty, managers of academic computing centers, and administrators – who must ultimately make the decisions, and who are equipped with the knowledge and experience to do the best job possible with the available resources.

REFERENCES

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9. Oregon State University, First Report on an Exploratory Program of Regional Cooperative Computing Authorities, Report on an NSF Program, *January 1969.*

10. Solomon, Martin B., Economies of Scale and Computer Personnel, *Datamation, Vol. 16,* No. 3, pp. 107-110, *March 1970.*

11. Minnesota Higher Education Coordinating Commission Staff.

APPENDICES

H.1 Visits and Consultations Related to the Minnesota Statewide Study of Computing Facilities in Higher Education, P. G. Roll and P. C. Patton, March-July 1970.

H.2 Report on Minnesota Computer-Based Library Network, Peggy Cabaniss and Robert M. Hayes, Becker and Hayes, Inc., Los Angeles, June 1970.

H.3 Educational and Economic Feasibility of Computer-Assisted Instruction, Russell W. Burris, Center for Research in Human Learning, University of Minnesota, July 1970.

H.4 Academic Computing at the University of Minnesota, 1969-1975, Frank Verbrugge, Director of University Computer Services, July 1970.

H.5 Tables Summarizing Existing (August 1970) Computing Facilities and Programs in Minnesota Higher Education.

H.6 Analysis of Goals and Computer Resources Needed for Minnesota Higher Education.

H.7 Tables Detailing Facilities to Meet the Goals and Cost Analysis.

H.8 A Cost Comparison of Time-Shared and Remote Job-Entry Computing.

H.9 Deployment Configuration for Higher Education Computer Networks.

H.10 Summary of Enrollment Data and Projections for Minnesota Post-Secondary Education.

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 – July 15, Peter G. Roll and Peter C. Patton

Date	Institutions	Persons Involved	Title or Position
Tuesday March 24	State College Board	John Haugo	Director, Information Systems
		Norman Dibdahl	Vice-Chancellor, Administration
Wednesday March 25	University of Minnesota	Frank Verbrugge	Director, Computer Services
Wednesday March 25	HECC	Computer-Library Sub-committee	
Wednesday March 25	HECC	Computer Advisory Committee	
Thursday March 26	State Junior College Board	Donald Wujcik	Assistant to Chancellor, Fiscal Services
		Banning Hanscomb	Assistant to Chancellor, Student Services
Monday March 30	University of Minnesota	Russell Burris	Executive Officer, Center for Research in Human Learning
Monday March 30	University of Minnesota	Luther Pickrel	Director of Analytical Studies
Tuesday March 31	*HECC	Richard Hawk	Executive Director
Tuesday March 31	*Anoka-Ramsey SJC	Curtis Austin	Faculty
		Thomas Loftus	Faculty

*P.G. Roll only

Appendix H. 1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 – July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Wednesday April 1	*Lakewood SJC	Martin Murphy	Administrative Assistant and Director of Computer Center
Wednesday April 1	University of Minnesota	Stephen Kahne	Director, Digigraphics and Hybrid Lab
		R.P. Halverson	Acting Director, University Computer Center
Friday April 3	Mankato State College	Donald Henderson	Director of Computer Services
		Kent Alm	Executive Vice-President
		Dale Carrison	Executive Director of Libraries
		Dan Lester	Librarian
		Edward McMahon	Coordinator of Instructional Research
		John Odom	Coordinator, Secondary School Computer Project
		Ronald E. Eick	Asst. Vice President, Admin. Affairs
		David Lewis	Faculty, Mathematics
		Paul D. Waldorf	Faculty, Languages
Friday April 3	Mankato Area Vocational-Technical Institute	F.G. Kalin	Director
		John Vocta	Assistant Director
		Dale Klooster	Instructor
		D.L. Buckholtz	Instructor

*P.G. Roll only

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 – July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Friday April 3	Mankato Area Vocationa-Technical Institute	D.E. Monson	Instructor
		K.N. Schweim	Instructor
		C.N. Swanson	Instructor
Monday April 6	Private College Council	Edgar Carlson	Executive Director
Monday April 6	State Department of Education	Robert Madson	
Tuesday April 7	State Department of Education	Howard Casmey	Commissioner of Education
		Farley Bright	Associate Commissioner of Education
		Harlan Sheeley	Director, Information Systems
		Dan Magraw	Assistant Commissioner of Administration
Wednesday April 8	Rochester Area Vocational-Technical Institute	Emil Heintz	Director
		Kenneth Garland	Assistant Director
Wednesday April 8	Rochester State Junior College	Verlyn Heldt	Dean of Instruction
		A. Hesse	Faculty
		Wilbur Wakefield	Director, University of Minnesota – Rochester Extension Center

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 — July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Wednesday April 8	Winona State College	Norman Decker	Vice-President for Administration
		David Hamerski	Director, Computer Center
		David Forsythe	Assistant Registrar
Monday April 13	St. Cloud State College	A. Lease	Vice-President for Administration
		Louis Hird	Director, Computer Center
		Robert Ryan	Faculty, Industrial Education
		James Marmas	Dean, School of Business
		Florence Stennis	Faculty, Mathematics
		Luther Brown	Director of Learning Resources
		Donald Sikkink	Dean of Arts and Science
Monday April 13	St. Cloud Area Vocational-Technical School	Willard Murphy	Administrative Assistant, ISD 742
		James Wakefield	Director
Tuesday April 14	St. Paul Area Vocational-Technical School	Data Processing Committee, Board of Vocational Education	
Tuesday April 14	Control Data Corporation	Russell Johnson	Sales
		Steven Rickelman	Sales
		Dennis Wright	CDC Coordinator, California State College Computer System
Tuesday April 14	Department of Administration	Dan Magraw	Assistant Commissioner of Administration
Wednesday April 15	HECC	Computer-Library Subcommittee	

Appendix H. 1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 – July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Thursday April 16	*University of Minnesota	D.K. Smith	Vice President, Academic Administration
Thursday April 16	University of Minnesota School of Business Administration	Gordon Davis	Director, Management Information Systems Research Center
Thursday April 16	University of Minnesota	Stephen Kahne	Director, Hybrid-Digigraphics Computer Lab
		Staff, Hybrid-Digigraphics Lab	
		Staff representatives of various State agencies	
Monday April 20	Willmar Area Vocational-Technical School	Mike Cullen	Director
		Roger Aspinson	
		Don Cash	Faculty
Monday April 20	Willmar State Junior	John Torgelson	President
		Richard Brunner	Instructor, Mathematics
		William Benson	Instructor, Physics
Monday April 20	Southwest Minnesota State College	Larry Hunter	Director of Information Systems
		Carroll Harrison	Director of Instructional Resources
		Joseph Rossillon	Assistant to President
		Robert Johnson	Director, Public Services and Development

*P.G. Roll only

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 — July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Monday April 20	Southwest Minnesota State College	Hilary Egan	Business Manager
		M.E. Kelke	Dean, Student Affairs
		Ann Atkins	Student Intern
		Ralph Frazier	Chairman, Division of Math and Science
		John Lewther	Faculty, Mathematics
		Soren Munkhof	Head, Radio and Television
Tuesday April 21	University of Minnesota College of Education	Douglas Anderson	Faculty, Educational Psychology
		Vernon Hendrix	Faculty, Educational Administration
		O.C. Hooker	Head, Division of Educational Administration
Thursday April 23	*Bemidji State College	A. Lorents	Director, Computer Center (on leave at University of Minnesota)
Thursday April 23	*TIES	David Lewis	Burnsville School Board
Monday April 27	*Duluth Area Vocational-Technical School	Robert Bergstrom	Director
		Eldon Johns	Assistant Director
		Kenneth Hausauer	Chairman, Business Division
		Keith Desilet	Instructor

*P.G. Roll only

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 — July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Monday April 27	*University of Minnesota Duluth	John Gergen	Director, Computer Center
		Donald Harris	Chemistry
		Dean Kjolhaug	Student Affairs
		Cecil Meyers	Economics
		Harry Zabrocki	Business
		Alvin Oldenburger	Secondary Education
		(This group is the Faculty Advisory Committee to the University of Minnesota Duluth Computer Center.)	
Tuesday April 28	*Hibbing Area Vocational-Technical School	William Magajna	Director
		Ernest Bylkas	Instructor, Programming
		James Bodes	Instructor, Mathematics and Statistics
		Louis Piantoni	Instructor, Business and Accounting
		Leon Cross	Instructor, Programming
Tuesday April 28	*Hibbing State Junior College	Donald Penn	Physics
		Merrill Widmark	Mathematics
Tuesday April 28	*Itasca State Junior College	Harold Wilson	President
		Leo Keskinen	Dean of Instruction
		Lyle Geesing	Mathematics

*P.G. Roll only

Appendix H. 1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 – July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Tuesday April 28	*Itasca State Junior College	Thomas Ademson	Mathematics
		Robert Schwob	Biology
		Charles Young	Physics
Wednesday April 29	Bemidji State College	Ray Carlson	Dean of Students, Director, Institutional Resources
		Lyle Dalley	Director, Computer Center
		Roger Baker	Business Education
		Ken Masse	Mathematics and Computer Science
		Sam Feistner	Mathematics and Computer Science
		Lester Mattison	Director of Libraries
		Lowell Vaughan	Education, Director of Extension
		William Sliney	Area Coordinator, Cooperative Extension Service, University of Minn.
Thursday April 30	Moorhead State College	Martin Holoien	Director, Computer Center
		Arden Berg	Business Manager
		Lester Johnson	Office of Administrative Dean
		John McEwen	Assistant to the President
		Larry Reed	Assistant Librarian
		Rodney Erickson	Assistant Librarian
Thursday April 30	Concordia College	Carl Bailey	Dean
		Arnold Garness	Mathematics, Director of Computer Center

*P. G. Roll only

Appendix H. 1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 – July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Thursday April 30	Concordia College	David Smedstad	Business Office
		Robert Brummond	Physics
		Lawrence Falk	Economics
		James Ulness	Psychology
		Gustav Duiga	Chemistry
		Carl Scheie	Physics
		Albert Anderson	Provost, Tri-College University
Tuesday May 5	IBM	Paul Gustafson	GEM Sales
		Wayne Carlson	GEM Sales
		Charles Grimsrud	GEM Sales
Thursday May 7	Normandale State Junior College	Arland Otte	Dean of Instruction
		Gregory Greer	Physics
		Chris Deibel	Physics
		Terry Florin	Psychology
		David Hardin	Engineering Technology
		Glen Oster	Recorder
Friday May 8	University of Minnesota Library	Audrey Grosch	Systems Coordinator
		Glenn Brudvig	Bio-Medical Library
		Eugene Lourey	Systems Analyst
		Ralph Hopp	University Librarian
Tuesday May 12	*State Junior College Board	Junior college instructional computing coordinators and staff of Honeywell Information Services Division and EDINET project.	

*P. G. Roll only

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 — July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Wednesday May 13	St. Paul Area Vocational-Technical School	Data Processing Committee Board of Vocational Education	
Friday May 15	Alexandria Area Vocational-Technical School	Vernon Maack	Director
		Robert Pesola	Instructor
		Elvin Lund	Instructor
		Hugh Kabrick	Instructor
		Connie Kouba	Computer Coordinator, Instructor and Consultant
		Viola Halvorson	Alexandria School District
		James Van Tassell	IBM Sales
Tuesday May 19	State College Board	Robert Johnston	Systems Analyst
Wednesday May 20	Macalester College	Richard D. Paulson	Director, Computing Service
		Janet Griffin	Programming Supervisor
Wednesday May 20	University of Minnesota	Marvin Stein	Director, Computer Center
		Eugene Ackerman	Director, Division of Health Computer Sciences
Thursday May 21	*Metropolitan State Junior College	State Junior College Learning Resources Conference	

*P.G. Roll only

Appendix H. 1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 — July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Friday May 22	Department of Education	Harlan Sheeley	Director of Information Services
Friday May 22	Honeywell, Information Services Division	Robert F. Trocchi	Manager, Educational Services
		Bruce Crane	Branch Manager
		John Knowlton	Sales
		Dale LaFrenz	Educational Consultant, EDINET
Tuesday May 26	Macalester College	Kenneth Goodrich	Dean, Educational Research
		Richard D. Paulson	Director, Computer Services
Wednesday May 27	State College Board	John Haugo	Director, Information Systems
Monday June 1	Visit of Dr. R. Brady (Ohio State University) as a consultant	John Haugo	Director, Informations Systems State College Board
		Dan Magraw	Assistant Commissioner of Administration
Monday June 1	**University of Minnesota	Luther Pickrel	Director of Analytical Studies
		Russell Burris	Center for Research in Human Learning
		Frank Verbrugge	Director of University Computer Service
		D.K. Smith	Vice-President for Administration
		Hale Champion	Vice-President for Planning and Development

**Meetings held at University of Minnesota

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 — July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Thursday June 4	*Cleveland State University	J. Soules	Dean, Arts and Sciences
		Arnold Tew	Assistant Dean, Arts and Sciences
		Frank Marzocco	Director, Computer Services
Thursday June 4	*Case-Western Reserve University and Chi Corporation	E. Glaser	Chairman, Computer Science
Friday June 5	*Ohio State University	Roy Reeves	Director, Instructor and Research Computer Center
		Ronald Dixon	Operations Manager Public Service Computer Center
		William Irion	Director, Administrative Services Computer Center
		Eugene Leiderman	CAI Coordination Staff
		G.W. Baughman	Director of Administrative Research
		E. L. Jossem	Head, Department of Physics
Saturday June 6	*Ohio State University	R. Brady	Executive Assistant to President
Monday June 8	Visit of Dr. R.M. Hayes (UCLA) as consultant on library automation, June 8-10	Audrey Grosch	Systems Coordinator, University Library
		Glen Brudvig	University Bio-Medical Librarian
		Eugene Lourey	Systems Analyst, University Library

*P.G. Roll only

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 — July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Tuesday June 9	University of Minnesota	Russell Burris	Executive Officer, Center for Research in Human Learning
		F. Verbrugge	Director, University Computer Services
		D.K. Smith	Vice-President, Administration
		Hale Champion	Vice-President, Planning and Development
		W.G. Shepherd	Vice-President, Academic Administration
		HECC Library Technical-Advisory Committee and Computer-Library Sub-committee	
	State Department of Education	Hannis Smith	Director, Public Library Section
	Southwest Minnesota State College	Carroll Harrison	Director, Instructional Resources
	Mankato State College	Dale Carrison	Director of Libraries
		Daniel Lester	Librarian
	State College Board	John Haugo	Director of Information Services
Wednesday June 10	Minneapolis Public Library	Ervin Gaines	Director
		Miss Wallace	Systems Staff

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 — July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Wednesday June 10	Hennepin County Library	R. H. Rolph	Director
Wednesday June 10	Hill Reference Library	Herman Henkle	Director
Wednesday June 10	Department of Education	R. K. Anderson	Staff, Vocational-Technical Education
Wednesday June 10	HECC	Joseph LaBelle	Assistant Executive Director
		Richard Hawk	Executive Director
Thursday June 11	*IBM	Richard Stanwood	Ohio State University Library Project, IBM
		Paul Gustafson	GEM Sales
		Russell Burris	Executive Officer, Center for Research in Human Learning
Tuesday and Wednesday June 16-17	University of Iowa	Conference on Computers in the Undergraduate Curricula	
Thursday June 18	*IBM	Al Warheid	Library Systems Development
		Paul Gustafson	GEM Sales
		Wayne Carlson	GEM Sales
		F. Verbrugge	Director, University Computer Services

*P.G. Roll only

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 — July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Thursday June 18	*University of Minnesota	Russell Burris	Executive Officer, Center for Research in Human Learning
		W. Simonton	Library School
		R. P. Halverson	Director, University Computer Center
Thursday June 18	*State Junior College Board	Data Processing Committee	
Friday June 19	*Macalester Foundation for Higher Education	Gerald Kieffer	Director
	Department of HUD and University of Oregon	William Mitchell	Consultant, Analysts International Corporation
	Analysts International Corporation	John Hackley	State Study Staff
Tuesday June 23	St. Thomas College	Twin Cities College Computer Committee	
Wednesday June 24	University of Minnesota	Frank Verbrugge	Director, University Computer Services
		Francis M. Boddy	Associate Dean, Graduate School
		John R. Borchert	Director, Center for Urban and Regional Affairs
		Thomas L. Anding	Executive Director, Upper Midwest Research and Development Council
		John S. Hoyt	Program Leader, Agricultural Extension

*P.G. Roll only

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 — July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Friday June 26	*Lakewood State Junicr College	Martin B. Murphy, Jr.	Administrative Assistant and Director, Computer Center
Tuesday June 30	State Junior College Board	Philip C. Helland	Chancellor
		Howard E. Bergstrom	Assistant to Chancellor, Curriculum
		Banning L. Hanscomb	Assistant to Chancellor, Student Services
		Donald J. Wujcik	Assistant to Chancellor, Fiscal Services
Thursday July 2		Clint Lomis	State Communications Engineer
Thursday July 2	University of Minnesota	Ralph Willard	Manager, Data Processing Center
		Theodore E. Kellogg	Dean, Admissions and Records
		Harold A. Ludke	Data Processing Operations Supervisor
		James J. Zdechlik	Computer Programming Supervisor
		Fred Seagren	Analyst
Monday July 6	University of Minnesota	Donald K. Smith	Vice-President, Administration
		W.G. Shepherd	Vice-President, Academic Administration

*P.C. Patton only

Appendix H.1. Visits and Meetings with Representatives of Post-Secondary Institutions and Systems, March 20 — July 15, Peter G. Roll and Peter C. Patton (Continued)

Date	Institutions	Persons Involved	Title or Position
Monday July 6	University of Minnesota	Hale Champion	Vice-President, Planning and Operations
		Frank Verbrugge	Director, University Computer Services
Tuesday July 7	St. Paul Area Vocational-Technical School	Data Processing Committee Board of Vocational Education	
Wednesday July 8	*University of Minnesota	Harry Ludke	Data Processing Operations Supervisor
		James J. Zdechlik	Computer Programming Supervisor
Monday July 13	University of Minnesota	Donald K. Smith	Vice-President, Administration
		W.G. Shepherd	Vice-President, Academic Administration
		Hale Champion	Vice-President, Planning and Operations
		Frank Verbrugge	Director, University Computer Services
		Francis M. Boddy	Associate Dean, Graduate School
		John R. Borchert	Director, Center for Urban and Regional Affairs
		Thomas L. Anding	Executive Director, Upper Midwest Research and Development Council
		John S. Hoyt	Program Leader, Agricultural Extension
		Stephen Kahne	Director, Hybrid and Digigraphics Laboratory

*P.G. Roll only

APPENDIX H.2

REPORT ON MINNESOTA COMPUTER-BASED LIBRARY NETWORK

Peggy Cabaniss
Robert M. Hayes

26 June 1970

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...geles, California 90024

Minnesota, like many other states, is considering the development of a statewide library network that involves compacts among libraries for sharing of resources, union catalog production, centralized technical services, and mechanized information services. Within this framework, there are already a number of activities underway within the State, including several directly related to the subject of this report (namely, the general state of computing in higher education and government within Minnesota). It is the purpose of this Appendix of the report to recommend a technical and organizational plan for developing and implementing a statewide computer-based system to serve library needs, and which will build upon the existing efforts.

In order to realize the goals for a statewide network, it is recommended that Minnesota consider developing four levels of service:

1. Catalog Production Services — The functions of this facility, whose basic purpose is to provide centralized union catalog production services, include the following:

    - Establish a standardized format for catalog data consistent with that used in the MARC tapes from the Library of Congress
    - Act as a central receiving point for catalog data from national and local library sources
    - Convert catalog data into a standardized format
    - Produce book catalogs of various types for central and local needs

2. Central Technical Processing Services — Individual libraries can contract with this facility for such services as central ordering, cataloging, card production, and book preparation.

3. Mechanized Information Services — This service provides the capacity to acquire, catalog, and provide information from magnetic tape data bases of all kinds — reference, numerical, and text — such as the Census Bureau tapes, Chemical Abstracts Tapes, legal text files, etc.

4. On-Line Bibliographic Services — The purpose of this service is to maintain bibliographic data on disk files and to provide on-line

access to these files for libraries throughout the state. Libraries will be able to both query and add information to the data files.

In addition, an educational and training program should be established for the purpose of educating librarians and informing patrons about the operation of the system, available services, and procedures for using them. Figure 1 shows an organizational schematic and indicates the groups which might be responsible for developing these services in the statewide library system.

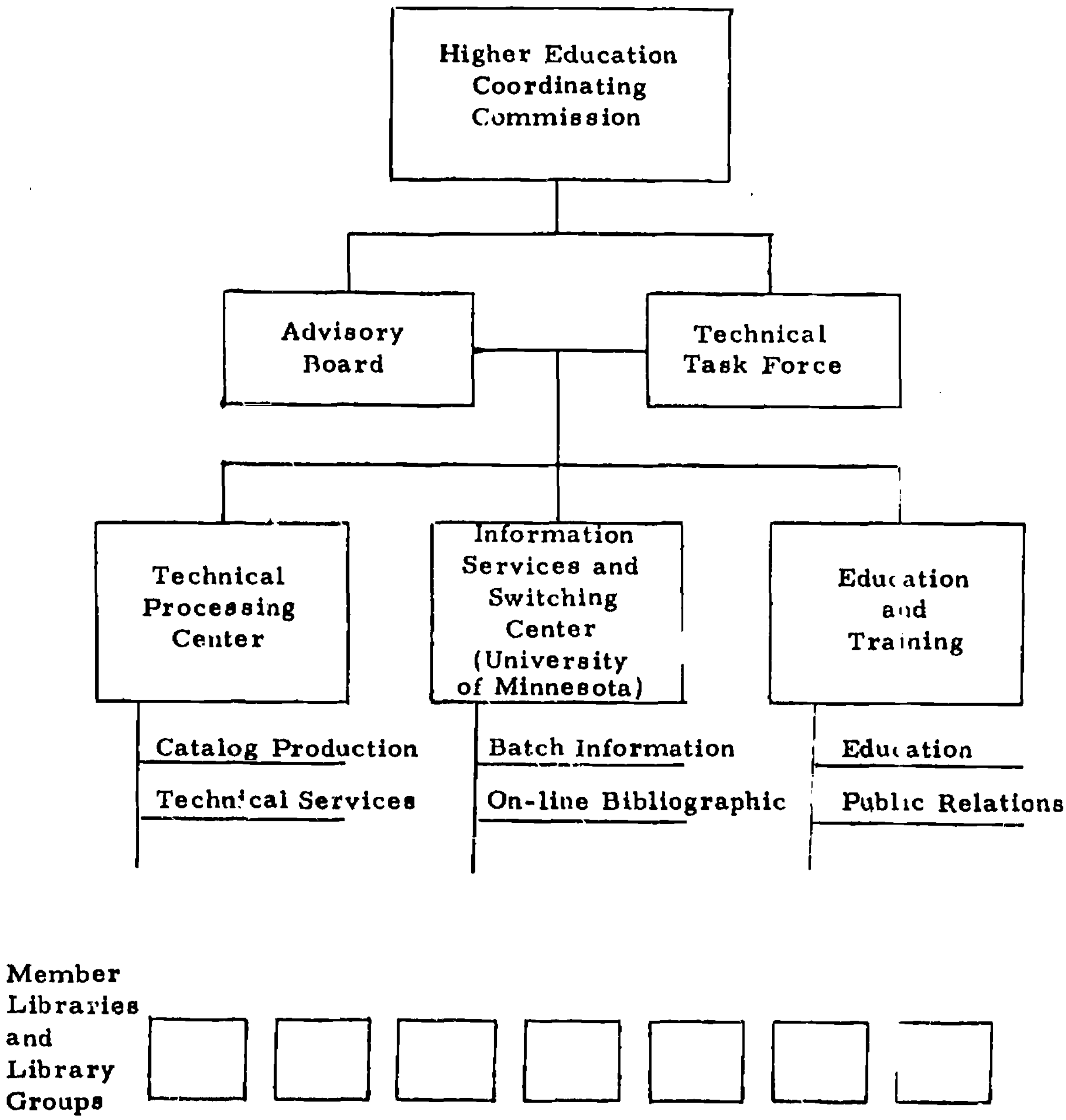
It is recommended that the Higher Education Coordinating Commission serve as the administrative focal point of the system. Its primary function would be to receive money from the State for the development, implementation, and operation of the system. It would arrange for contractors to carry out the technical work needed to develop, implement, and maintain various parts of the system. An Advisory Board and a Technical Task Force would serve as coordinating and policy advising bodies. Specifically, the responsibility of the Advisory Board, composed of librarians representing various types of libraries and library groups, is to guide the Commission on what should be done within the State network. The Technical Task Force, whose members are from the systems analysis staffs of libraries and library groups, is responsible for establishing the specifications of the system and assuring that the network is developed to meet the needs of the library community as determined by the Commission and the Advisory Board.

At present, Hennepin County appears to be a reasonable choice as the contracting agency for development and operation of the Catalog Production Services and for the Technical Processing Services. They have computer facilities for providing such services; the Hennepin County Library already has embarked on a catalog production effort.

Likewise, the University of Minnesota Library, the State's largest bibliographic resource, appears to be the logical agency to develop mechanized information services and to act as the Switching Center and on-line bibliographical center for the network. The University has already recommended the development of an automated system for providing on-line bibliographic services and mechanized information services (as documented in the report, Hardware/Software Requirements Information for a Minnesota Computer-Aided Library System).

FIGURE 1

Organizational Schematic for the Proposed Library Network in the State of Minnesota



There appears to be no existing agency that could be made responsible for Education and Training as a 'continuing education' function. The Higher Education Coordinating Commission should make an early effort to contract for the development of this facility. A group (or groups) with experience in providing such a program should work in cooperation with the University of Minnesota Library School.

There are six phases in the development and implementation of each of these four levels of service. Each phase can be separately budgeted in terms of time and money, but each is a necessary step toward realizing the operational system.

1. Phase 1 — Management: This stage establishes the basic management and administrative capability to provide long-range, continuing direction for the network, and its development.

2. Phase 2 — Feasibility and Specification: During this phase, the feasibility of the service is established, the preliminary specifications for its operation are developed, and the time sequence for subsequent stages in the development and operation of the system are established.

3. Phase 3 — Training, Education, and Public Relations: The purpose of this stage is to acquaint the staff, in those libraries which are participating (or potentially participating) in one or more aspects of the system, with the nature of the service, the requirements for participating, the advantages and potential difficulties, etc.

4. Phase 4 — Development and Implementation: The operational capabilities of the service are created during this stage.

5. Phase 5 — Operation: The facility is operating and providing services to libraries and their users during this phase.

6. Phase 6 — Maintenance: This phase provides for the continuing review, correction, and improvement of the on-going operational service.

Various phases of each service can be separately funded from local, state, and national sources, as outlined in Figure 2. In particular, the Commission should be responsible for the major commitment of funds for development, training, and

Phases	Technical Processing Center	Information Processing Center (University of Minnesota)
Management and Administration	State Department of Education	University of Minnesota
Specification, Training, Implementation and Development	Higher Education Co-ordinating Commission	Higher Education Co-ordinating Commission
Operation and Maintenance	Fees	Fees

Figure 2. Sources of Income for Funding a Statewide Library Network

implementation. However, it is recommended that the University establish support for management and administration of the work assigned to it within its own budget. Similarly, Hennepin County should be separately funded for the management and administration of the Technical Processing and Catalog Production Services. Since the State Department of Education has the authority to allocate funds under the Library Services and Construction Act, they represent an appropriate agency to provide funding of this phase for the Technical Processing Center. A scale of fees should be established so that the costs of operation and maintenance would be covered by charges to the participating libraries for services provided to them.

The following tables provide estimates of the budgets necessary to accomplish the goals of each phase in the four services. Tables H.2.1 through H.2.4 project total costs by service for a five-year period. Tables H.2.5 through H.2.9 show the costs by year for the four services. Overhead, which has been included, is calculated at 57%, including 45% for basic overhead and 12% for benefits. The estimates are drawn in part from those in the proposal from the University of Minnesota, but have been modified to include consideration of the additional services, a different time schedule, and other sources of estimates.

It is unlikely that the cost of developing the system can be justified on the basis of direct cost savings. Therefore, a careful analysis must be made of benefits. These include the sharing of resources, the access to larger sources of information, better handling of requests, reduction in duplicate work, and more rapid access to materials. Therefore, at an early point during the development of the system, a full cost/benefit study should be contracted for in order to evaluate the benefits from the services offered, their unit costs, and their future costs.

Table H.2.1. Estimated Costs for Catalog Production Services

Phase	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Management*	47,000	47,000	47,000	47,000	47,000	235,000
Feas. and Spec.	20,000					20,000
Educ. and Train.	40,000	10,000	10,000	10,000	10,000	80,000
Dev. and Impl.	10,000					10,000
Subtotal	117,000	57,000	57,000	57,000	57,000	345,000
Overhead	66,700	32,500	32,500	32,500	32,500	196,700
Subtotal	183,700	89,500	89,500	89,500	89,500	541,000
Operat.**	250,000	500,000	500,000	500,000	500,000	2,250,000
Maintenance		30,000	30,000	30,000	30,000	120,000
Total	433,700	619,500	619,500	619,500	619,500	2,911,700

Notes shown on page H.2-11.

Table H.2.2. Estimated Costs for Central Technical Processing Services

Phase	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Management*						
Feas. and Spec.						
Educ. and Train.						
Dev. and Impl.	60,000	200,000	200,000			460,000
Subtotal	60,000	200,000	200,000			460,000
Overhead	34,200	114,000	114,000			262,000
Subtotal	94,200	314,000	314,000			722,000
Operat. ***			250,000	1,000,000	1,000,000	2,250,000
Maintenance				100,000	100,000	200,000
Total	94,200	314,000	564,000	1,100,000	1,100,000	3,172,200

Table H.2.3. Estimated Costs for Mechanized Information Services

Phase	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Management	47,000	47,000	47,000	47,000	47,000	235,000
Feas. and Spec.	20,000					20,000
Educ. and Train.	8,000	16,000	8,000	8,000	8,000	48,000
Dev. and Impl.	35,000	170,000	360,000			565,000
Subtotal	110,000	233,000	415,000	55,000	55,000	868,000
Overhead	62,700	132,800	236,500	31,400	31,400	494,800
Subtotal	172,700	365,800	651,500	86,400	86,400	1,362,800
Operation				606,000	606,000	1,212,000
Maintenance				70,000	70,000	140,000
Total	172,700	365,800	651,500	762,400	762,400	2,714,800

Notes shown on page H.2-11.

Table H.2.4. Estimated Costs for On-Line Bibliographic Services

Phase	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Management	47,000	47,000	47,000	47,000	47,000	235,000
Feas. and Spec.	100,000					100,000
Educ. and Train.		40,000	10,000	10,000	10,000	70,000
Dev. and Impl.		480,000	480,000			960,000
Subtotal	147,000	567,000	537,000	57,000	57,000	1,365,000
Overhead	83,800	323,200	306,000	32,500	32,500	778,000
Subtotal	239,800	890,200	843,000	89,500	89,500	2,143,000
Operat.				800,000	800,000	1,600,000
Maint.						
Total	230,800	890,200	843,000	889,500	889,500	3,743,000

Table H.2.5. Estimated Costs for Services During Year 1

Phase	Catalog Production	Central Processing	Mechanized Information Services	On-Line Services	Total
Management	47,000		47,000	47,000	141,000
Feas. and Spec.	20,000		20,000	100,000	140,000
Educ. and Train.	40,000		8,000		48,000
Dev. and Impl.	10,000	60,000	35,000		105,000
Subtotal	117,000	60,000	110,000	147,000	434,000
Overhead	66,700	34,200	62,700	83,800	247,400
Subtotal	183,700	94,200	172,700	230,800	681,400
Operat.	250,000				250,000
Maintenance					
Total	433,700	94,200	172,700	230,800	931,400

Table H.2.6. Estimated Costs for Services During Year 2

Phase	Catalog Production	Central Processing	Mechanized Information Services	On-Line Services	Total
Management	47,000		47,000	47,000	141,000
Feas. and Spec.					
Educ. and Train.	10,000		16,000	40,000	66,000
Dev. and Impl.		200,000	170,000	480,000	850,000
Subtotal	57,000	200,000	233,000	567,000	1,057,000
Overhead	32,500	114,000	132,800	323,200	602,500
Subtotal	89,500	314,000	365,800	890,200	1,659,500
Operat.	500,000				500,000
Maintenance	30,000				30,000
Total	619,500	314,000	365,800	890,200	2,189,500

Table H.2.7. Estimated Costs for Services During Year 3

Phase	Catalog Production	Central Processing	Mechanized Information Services	On-Line Services	Total
Management	47,000		47,000	47,000	141,000
Feas. and Spec.					
Educ. and Train.	10,000		8,000	10,000	28,000
Dev. and Impl.		200,000	360,000	480,000	1,040,000
Subtotal	57,000	200,000	415,000	537,000	1,209,000
Overhead	32,000	114,000	236,500	306,000	688,500
Subtotal	89,000	314,000	651,500	843,000	1,897,500
Operat.	500,000	250,000			750,000
Maintenance	30,000				30,000
Total	619,000	564,000	651,500	843,000	2,677,500

Table H.2.8. Estimated Costs for Services During Year 4

Phase	Catalog Production	Central Processing	Mechanized Information Services	On-Line Services	Total
Management	47,000		47,000	47,000	141,000
Feas. and Spec.					
Educ. and Train.	10,000		8,000	10,000	28,000
Subtotal	57,000		55,000	57,000	169,000
Overhead	32,500		31,400	32,500	96,400
Subtotal	89,500		86,400	89,500	265,400
Operat.	500,000	1,000,000	606,000	800,000	2,906,000
Maintenance	30,000	100,000	70,000		200,000
Total	619,500	1,100,000	762,400	889,500	3,371,400

Table H.2.9. Estimated Costs for Services During Year 5

Phase	Catalog Production	Central Processing	Mechanized Information Services	On-Line Services	Total
Management	47,000		47,000	47,000	141,000
Feas. and Spec.					
Educ. and Train.	10,000		8,000	10,000	28,000
Dev. and Impl.					
Subtotal	57,000		55,000	57,000	169,000
Overhead	32,500		31,400	32,500	96,400
Subtotal	89,500		86,400	89,500	265,400
Operation	500,000	1,000,000	606,000	800,000	2,906,000
Maintenance	30,000	100,000	70,000		200,000
Total	619,500	1,100,000	762,400	889,500	3,371,400

Notes for Tables H.2.1 and H.2.2.

*The management and administrative costs are shared for catalog production and technical processing services.

**Assumes the production of one union catalog during the first year and two union catalogs during each of the following years, including the cost of converting library catalogs to machine-readable form.

***Based on processing 150,000 volumes during year 3 and 600,000 volumes during years 4 and 5.

APPENDIX H.3

THE EDUCATIONAL AND ECONOMIC FEASIBILITY OF COMPUTER-ASSISTED INSTRUCTION

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Center for Research in Human Learning
University of Minnesota
July 1970

In *Computers in Higher Education: Report of the President's Science Advisory Committee*, of February 1967, the following paragraph appears concerning the development of computer usage in teaching-learning situations by machine-learner interaction[(1)]:*

> It has been proposed that computers be used for "computer-assisted instruction" in which the student interacts with the computer during a learning period. It is clear that much of this will involve more than passively following a previously prepared routine; it will involve data analysis and data presentation. Whether or not computer-assisted instruction using a computer becomes widely used is an educational and economic problem. Surely, however, the cost of trying to find how it works is a legitimate educational expense.

Nearly 100 research and development efforts in the United States, Canada and Europe have been initiated during the past five years to study the educational validity of computer uses in instructional situations. Most of these efforts, of course, have been initiated only in the past two years[(2)]. While the majority of these efforts are located within institutions of higher education, several are sponsored by public and private school districts, and many are directed toward supporting industrial and military training programs.

The primary questions guiding these research efforts have been concerned with the educational and psychological validity of various computer-based instructional strategies, e.g., drill and practice, tutorial or programmed instruction, learner controlled, and simulation or problem solving situations. Another area of research and developmental effort in computer use often included in the consideration of CAI is CMI (computer-managed instruction). In CMI, the student does not interact with the computer program directly, but rather the instructor uses the computer to make instructional management decisions for prescribing sequences and content for individual students. Over the past two or three years, evidence has been gathered from these efforts which indicate substantial educational potential of such computer use in instruction[(3, 4, etc.)]. Evidence is less clear, however, whether such uses of the computer can be economically feasible.

*Reference numbers in this Appendix refer to the Bibliography accompanying it, not to the references for the entire report.

Many questions involved in a thorough analysis of the CAI-CMI cost-effectiveness remain unanswerable from current evidence. If viewed strictly as an add-on cost to current instructional costs, CAI-CMI is not economically feasible. However, if such computer uses are viewed as components in redesigned instructional strategies, there is some evidence of true economic feasibility.

Costs for operating a student terminal in currently operating systems varies between $2 and $5 per student-hour for each terminal[5]. These cost calculations include computer, systems software, terminal hardware, facility management, and communications leased or amortized over five years. As noted earlier, however, nearly all of the current installations are for research and developmental efforts, and for this reason more efficient operating systems could be designed with presently available equipment. Estimates have been made for systems using presently available equipment which vary between $0.40 and $1.60 per student-hour per terminal. These designs are based on systems which have between 30 and 100 terminals. These estimates have been reported by Bunderson at the University of Texas[5], Bitzer and Alpert[6] at the University of Illinois, and Robert Seidel at HUMRRO[7]. Each of the reported systems uses a different medium-size computer as a central processor to support the 30 to 100 student terminals consisting of at least CRT displays and keyboards. The higher estimates are accounted for by terminals which also include random access image projectors and random access audio devices. Similar estimates have been made in the CAI project with the Center for Research in Human Learning at the University of Minnesota.

In a well-documented cost analysis of a system based on 4,000 terminals and using terminal equipment for which only production prototypes exist at the present time, Bitzer and Alpert[6] estimate costs of between $0.34 and $0.68 per student-hour per terminal. They summarize the derivations of this estimate in the following table and reported the same in the article.

The above estimates do not include author costs involved in developing the instructional materials. These costs are estimated to vary between $100 and $800 per hour of instruction. When calculated over several hundred students and over 2 to 5 years of use, these costs add $0.10 to $0.25 per hour of instruction. These are usually hidden costs in current instructional designs, i.e., the development of special instructional materials, and, if funded directly, greater effectiveness and efficiency might be expected from the use

Table H.3.1. Operational Costs of the Plato IV System

	Total Annual Cost (Rental or Amortization Over 5-Year Period)	Annual Cost Per Student Station (Rental or Amortization Over 5-Year Period)	Cost Per Student Contact Hour*
Central Computer Facility	$900,000	$ 220	$ 0.00
Computer Systems Software	100,000	25	0.01
Student Console		360-1,000	0.18-0.50
Central Management Services	240,000	60	0.03
Communications Channels**		18-50	0.01-0.03
Total operational costs per student-contact hour			$0.34-0.68

*Annual use per student, 2000 hours (45 weeks at 44 hours per week); maximum number of student stations, 4096; total annual use (4096 stations), 8.2 million student-contact hours.

**For telephone connections on a given campus, contingent property-line costs are about $1.50 per month per terminal (1 cent per student-contact hour). For student stations at a distance, communications would be transmitted by means of time-multiplexed television channels for groups of 1000 student stations per channel. At a distance of 150 miles, this would cost an additional 2 cents per student-contact hour.

of these materials. Total author costs for developing supporting materials for instructional sequences now covered in a course might be expected to vary between $5,000 and $15,000.

C.V. Bunderson(5) has estimated a savings of approximately $55,000 in comparing a traditional instructional design with a new design using computer-assisted instructional materials. He shows a cost of $175,000 for teaching 1500 students in a class that meets 30 sessions over a term, and a cost of $119,400 for using computer-assisted instructional materials to support an instructor and assistants.

In order for CAI-CMI to be educationally viable and economically feasible, such uses of the computer must support new approaches and strategies in instructional design. Many new designs with these attractions have been demonstrated and reported in current research and developmental projects, including the project at the Center for Research in Human Learning at the University of Minnesota.

Drill and practice instructional materials in several areas of the curriculum at all levels of education have been demonstrated. At the elementary level, the computer has been used to control individualized drill and practice in reading and mathematics [8, 9]. Similar approaches have been used at the secondary and college levels in physics, mathematics, business education, statistics, art music and second languages [4, 10]. Several variations to this drill and practice strategy have been developed which might be described as programmed instruction, tutorial and learner controlled. These variations have to do with the elaborateness of the machine-learner interaction in the programmed software, and with the general sophistication expected of the learner in choosing his learning sequences.

Another type of instructional strategy which indicates significant educational effectiveness at the secondary, college and even continuing education levels is that of simulation. In such uses, a model of a large problem situation or system is programmed into the computer. The model can then be manipulated by the learner in ways which would be impossible, too expensive or too impractical in real situations. Simulations for effective instructional purposes have been demonstrated in medical education, business education, engineering, physical sciences and biological sciences [10, 11]. Many researchers and educators consider this area of computer application as having great potential for effective development. Using models of real world problems or situations, the student gains experiences unavailable to him previously, and the instructor is provided an environment to better consider the question of what a student 'knows' as he develops knowledge in a particular disciplinary area.

Computer-managed instruction (CMI) is often included as a particular type of instructional strategy along with CAI. The computer is used by the instructor to manage instructional materials for the evaluation of individual students. The effectiveness of this approach has been demonstrated at the elementary and secondary levels in the language, mathematics, social studies and science areas of the curriculum [12]. The major attractive feature of this strategy is the introduction of truly individualized approaches to instruction without the necessity of a dedicated on-line computer system. In the development of uses of CMI thus far, the evaluation of performance and prescription of instructional materials for individual students have been done off-line on a daily or even weekly basis.

Several features of these strategies have made them educationally attractive, and with reasonable hardware and software costs these systems could be truly cost-effective. Evidence indicates that lower ability students achieve at significantly higher levels than in traditional classroom environments, and that higher ability students take significantly less time to achieve at the same expected levels. With the individualization through the machine-learner sessions, a greater number of individual and small group sessions are scheduled to replace many of the larger classroom situations. Evidence from these new instructional arrangements suggests greater instructor effectiveness; in a real sense, the instructor becomes a manager of instruction with the ability to attend to individual learner needs in ways not possible before.

In a project titled, "A Computer-Based Research Project in the Optimization and Evaluation of Learning and Teaching", at the Center for Research in Human Learning at the University of Minnesota, drill and practice and simulation strategies have been developed and demonstrated in German, opthalmology, hematology, agricultural engineering design, and physics laboratory. Considerable developmental work has been done in obstetrics, orthodontics, and logic, and early efforts are underway in art, history, and geography. In the work accomplished to date, evidence indicates significant educational effectiveness is achieved by the drill and practice units covering the entire first year course in German, and by the simulations of clinical cases in opthalmology and hematology [10]. There are further indications that these and other expanded uses of the computer in second-language learning and in medical education can achieve a status of cost-effectiveness. There is no reason to believe that similar effectiveness will not be demonstrated as research and developmental efforts continue with other projects to develop instructional materials.

The projected costs of instruction at all levels over the next decade make new instructional approaches and designs imperative to achieve higher degrees of effectiveness. There is reason to believe that the expanding requirements of education can be met only through more effective use of both instructors and technology. To meet these new requirements, however, research and developmental efforts such as those at the Center for Research in Human Learning need to be continued in order to arrive at optimal educational designs that are economically feasible. With the remote capability of current technology, it is possible to continue the research and development facility at the Center for Research in Human Learning to support statewide needs in this area. Such a facility, including hardware and specialized personnel, could support the needs of departments at single institutions or the needs within disciplines at several institutions. There is no reason why instructors at several institutions could not develop cooperatively the instructional materials to be used in their own teaching designs. While this facility is seen presently as one to support instructional materials in higher education, it is possible that materials for elementary and secondary education could be developed at the same facility. Using the remote capability, initial demonstration efforts could be supported at any institution within the state to work out the design of an economically feasible system to be used in final implementation.

A statewide research and development facility for Minnesota would cost approximately $86,000 per year for hardware, system software, maintenance, and specialized support personnel over the next five years. The hardware costs, including computer and approximately 10 terminals, would cost $278,000 for the entire 5-year period. Personnel costs for system software and programming support would cost approximately $38,000 per year, and maintenance would add about $12,000 per year. As development proceeded, additional terminals up to a total of 30 could be added at a cost between $5,000 and $10,000 per terminal.

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APPENDIX H.4

ACADEMIC COMPUTING AT THE UNIVERSITY OF MINNESOTA 1969 – 1975

Frank Verbrugge, Director
University Computer Services
July 1970

H.4.1 Existing Computing Facilities

Academic computing facilities at the University are functionally divided into four groups:

1. General purpose facilities are those which serve the entire University for both instructional and research purposes. There are three such facilities at the University:

    a. University Computer Center — CDC 6600

    b. West Bank Computer Center — CDC 3200

    c. UMD Computer Center — CDC 3200

2. Special-purpose computing facilities are those which serve both instructional and research functions, but which are more specialized in orientation than those of Group 1 — specialized either in function or the academic units of the University which it serves. There are four such facilities:

    a. Health Science Computer Center — CDC 3300. This unit provides computing for research, for instruction and for public service in the health sciences.

    b. St. Paul Computer Center — IBM 360/30. The major function of this facility is to provide public service in agriculture-related activities; for the Dairy Herd Improvement Association, and in services related to soil analysis and farm management.

    c. Hybrid Computer Laboratory — EAI 680, CDC 1700. This facility is specialized primarily by two functions; it provides hybrid computation, and it has a high-speed interactive computer graphics capability. It is available for all University usage — for instruction, research, and public service.

d. Center for Human Learning -- IBM 1500 for the past two years, but to be replaced with another system still to be selected. The main focus of this system's use is research and development activities in computer-assisted learning.

3. Instructional Laboratory Computers -- Computers have become important instruments in non-computational laboratory instruction, particularly in professional programs in computer science and in engineering. These typically are stand-alone systems in the $100,000 to $300,000 range. Examples include:

   a. Systems designed for 'hands-on' experience in hardware and software design and in machine language instruction;

   b. Computer systems designed to facilitate analyses of engineering systems (for example, an 'integrated electronics' circuit) too complex for the more classical analysis by components;

   c. Laboratory computer systems which replicate modern industrial practices. For example, many chemical engineering departments now use a stand-alone laboratory computer as a controller for unit operations and for on-line data analysis of chemical engineering systems.

   Establishing laboratory computer systems, such as these, will most likely constitute an important component in the University's program for the next few years.

4. Special Purpose (non-computing) Research Computers -- Computers can be used for many purposes -- as controllers for research laboratory experiments, as communications devices, as data reduction systems, as monitors (e.g., hospital patient monitoring) and so forth. The University has many such systems in use; the earlier report, Computing at the University,* describes many of them. Typically, these are small computers, in the $5,000 - $50,000 price range.

*"Computing at the University, an Information Brochure prepared for the Computing Seminar," December 3, 1969.

In developing a statewide plan for computing for higher education, it is the University's Group 1 facilities that are of primary relevance. Group 2 and 3 facilities are of interest in assessing the need for establishing similar specialized facilities at other institutions. Group 4 facilities likely will not be involved in statewide planning for the foreseeable future – at least as a component in requests for appropriations. The rest of this report will focus primarily on Group 1, with some reference to Groups 2 and 3. Within Group 1, major attention will be devoted to the 6600, because it is the system with the largest reserve capacity.

H.4.2 Acquisition of Facilities

Funding for the acquisition of Group 1 and Group 2 computing facilities has been provided by three sources:

1. Federal grants and grants from industry.
2. University funding. (The University makes an allotment each year for computing equipment from funds generated by charges made for indirect costs associated with research grants and contracts. For 1969 - 1970, this allotment was $345,000.)
3. Income from services. This income source is applicable to both Group 1 and Group 2 facilities.

Nearly all funding for Group 4 facilities arises from direct grants, usually from a Federal agency.

The University requested, and received, $250,000 from the 1961 Legislature towards the acquisition of the CDC 1604. This system provided service for eight years – for most of that time, it was the University's only computing facility. It was offered as a trade-in for the Duluth campus CDC 3200 in 1969. No direct legislative funding has been involved for any facilities now in use at the University, even though they are heavily used for instructional purposes.

A summary of funding for the Group 1 and Group 2 facilities appears below as Table H.4.1:

Table H.4.1 Costs of Computing Facilities and the Sources of Funding

Group 1 – Facilities

System	Acquisition Plan	Purchase Price Net Cost	Funding Sources	
CDC 6600	7 yr. payment 1967 - 1973	$2,560,000	Federal grant	$ 800,000
			University	1,760,000
CDC 3200 (West Bank)	2 yr. payment 1967 - 1969	$ 450,000	Federal grant	$ 40,000
			Grants from Minnesota:	
			Industries	210,000
			University	200,000
CDC 3200 (UMD)	3 yr. payment 1969 - 1972	$ 440,000	University	$ 290,000
Total		$3,450,000 *		

*The original market value of this equipment is about $4,600,000 (about $3,700,000 for the total 6600 system). The $1,300,000 difference arises from educational discounts, research and development grants, and equipment 'trade-ins'.

Group 2 – Facilities

System	Aquisition Plan	Purchase Price Net Cost	Funding Sources	
CDC 3300 (Health Sciences)	3 yr. payment 1970 - 1973	$ 825,000	Income from:	
			Services	$ 650,000
			University	250,000
IBM 360/30	5 yr. payment 1969 - 1974	$ 365,000	Income from:	
			Services	$ 365,000
Hybrid	Purchase	$ 580,000	Federal	$ 400,000
			University	90,000
			Income from Services	90,000
IBM 1500	Lease	$7,500/month	Federal grant and University support.	

H. 4. 3 Distribution of Functions for Computing Facilities

At the University, so-called 'productive time' on a general-purpose academic computer is divided into four activities, as follows:

1. Faculty research -- this includes not only professional research, but also public service functions, such as those for state agencies, because these service activities are usually closely related to the faculty member's professional interests.

2. Computing for graduate student thesis research.

3. Course-related computing -- most of this computing is done by under-graduate students.

4. Systems development -- most of this developmental work is carried on by professional staff and by graduate students in computer science.

In addition to 'productive time', there is 'maintenance time' which usually is scheduled during 'non-prime' hours of the day. In an academic facility, 2000 hours of productive time per year for each eight hour shift is considered as an attainable goal; i.e., 6,000 hours per year or 500 hours per month approximates maximum utilization. For academic facilities, also, systems development is a very important component of productive time.

A summary of usage for the 6600 for the fiscal year 1969 -- 1970 appears in Table H.4.2 shown below:

Table H.4.2. Productive Usage of 6600 Computer 1969 -- 1970

Function	Hours of Use	% of Total Productive Use
Course-related	375	17%
Graduate Student	320	14%
Faculty Research (Including Public Service)	1,130	52%
Systems Development	389	17%
Total Hours	2,214	100%

By University policy, course-related and graduate student computing are considered to be instructional in character, and are, therefore, subsidized' by the University's support for the computer centers. Faculty computing can either be funded (from research grants) or subsidized. (Many faculty members look upon a computer facility as an instructional system, similar to a library, and, therefore a facility that should be fully 'subsidized' by the University.) Systems development is a research activity though it is highly instructional for the computer scientist, often a graduate student, who carries out the work. His work can be funded from research grants or can be subsidized.

The local interactive usage of the West Bank 3200 and the total usage of the UMD 3200 are largely instructional. The two 3200's have a combined computing power about one-fourth that of the 6600.

If one assumes that functions one and two of Table H.1.2 are 'entirely instructional' and functions three and four 'entirely research', the 6600 is used 31% for instruction. For the 6600 and the two 3200's combined, the percent instructional use is about 45%, that is:

$$\text{Percent Instructional Use} = \frac{(31\% \times 1) + (100\% \times 1/4)}{5/4}$$

$$= 45\%$$

In view of the uncertainties in definition, (particularly in identifying all of faculty computing as research), it is reasonable to state that at the present time, general-purpose computing (Group 1) divides itself about equally between instruction and research. It is virtually certain that for the foreseeable future, instructional usage will grow more rapidly than research usage. These considerations should be the basic elements in University budgetary planning for computing.

H.4.4 Anticipated Growth Patterns

1. The 6600 – The 6600 computer was installed in the spring of 1967. It has, therefore, been in use for three full years: 1967 -- 1968, 1968 – 1969 and 1969 – 1970. The growth rate between the 1967 – 1968 and 1968 – 1969 years was 45%. This, however, included

a phasing-out of the 1604 computer. Between 1968 - 1969 and 1969 - 1970, the growth has been 22%, or 450 hours of usage. 450 hours annual growth will, therefore, be assumed as the 'normal growth'.

There are a number of factors, both internal to the University and related to statewide planning, which indicate unusual incremental growth in computing during the next two to three years. These include the following:

a. There will be a major effort undertaken within the University to increase the computer usage among undergraduate students. A growth by a factor of three or four will bring us more nearly in line with many other Universities and with the recommendations of the Pierce Report (1).

b. Remote terminals at other institutions will likely add about one-half hour of computing per month (or 6 hours per year) for each 1000 students. A build-up period of three years is assumed, and a total student enrollment of 50,000 at the institutions involved, hence, a growth rate of 100 hours per year for a three year period. It should be noted that this load will not exceed 5-6% of total usage.

c. Public service activities will increase, particularly those related to 1970 census data. The growth could likely be almost unlimited. 100 hours per year for two years is assumed, then a leveling off of the annual increase to 50 hours.

d. The 6600 system is made available to many users, especially non-profit agencies. It is anticipated that this service will continue to grow.

These anticipated growths are summarized in Table H.4.3 below.

Table H.4.3. Anticipated Usage of the 6600 (Hours per year)

	1970/ 1971	1971/ 1972	1972/ 1973	1973/ 1974	1974/ 1975
Normal Growth	+ 450	+ 450	+ 450	+ 450	+ 450
Special Undergraduate Growth at the University	+ 200	+ 200	+ 200	+ 200	-
Remote Terminal Usage at Other Colleges	+ 100	+ 100	+ 100	-	-
Public Service	+ 100	+ 100	+ 50	+ 50	+ 50
Other	+ 50	+ 50	+ 50	+ 50	+ 50
Subtotal	+ 900	+ 900	+ 850	+ 750	+ 550
1969 – 1970 Usage	2,200				
Total Hours	3,100	4,000	4,850	5,600	6,150

Obviously, these statistics must be considered as approximate. It does indicate that by about 1973 – 1974, we will be approaching full loading of the 6600.

2. The 3200 Systems – Both systems have a capability for meeting the respective needs for a period of not less than three years. The capability is limited, primarily by the current size of central memory, namely, 32,000 'words'. These memories can be expanded in modules of 16,000 at a cost of about $55,000 per module.

H.4.5 Operating Support

As an approximate 'rule of thumb', the annual operating budget of an academic computing center should be about equal to the annual 'lease equivalent' of the equipment, which typically lies in the range of 25 - 30% of the purchase price of the equipment. For the Group 1 computers, this figure would be about $900,000 based on the $3,300,000 net price. (The $4,600,000 original market price actually would be the base on which lease rates should be calculated.) This has been our budget goal, supported about equally by regular support and by income from research – that is, in proportion to the instructional versus research computing loads.

The 1969 Legislature's inclusion of $200,000 in the University's appropriation designated for academic computer operating costs marked a major step forward. Most of the dollars were allotted to the three Group 1 centers; the remainder was allotted to the Hybrid Laboratory and the Center for Human Learning. The preliminary legislative requests for 1971 - 1973 would bring the operating support fully in line with the average standard identified above.

Of greater importance will be the need to make representation on behalf of all of higher education, that as the state embarks on a major expansion program of facilities, it be accompanied by adequate funding to meet operating costs.

H.4.6 Instructional Computing Needs for the Next Five Years

In this section are presented briefly the projected major areas of development for instructional computing at the University, both internally and in the context of a statewide program for higher education. The associated cost estimates must be viewed as approximate, especially for the last three years. Research equipment needs are not included except those for computer-assisted learning, because this research activity is directly related to instructional programs.

1. Group 1 Systems.

   a. The 6600. The addition of low-speed terminals to the 6600 for use by the University and by other institutions and agencies will require the addition of a disk system ($110,000), and communications controllers ($45,000 and $90,000). The terminals will cost about $30,000 each. For the University itself (including St. Paul and the branch campuses, except UMD), three per year are assumed for each of four years. An additional printer will also be needed ($75,000).

      If by 1973 - 1974 the 6600 is fully loaded, it can be expanded to a 6700 – at an overall cost of about $1,800,000. At that time, its load will be about 60% instructional; the proportionate hardware cost is $1,280,000. (The expansion of the 6600 is only one of many alternatives, of course.)

b. The 3200's. As previously pointed out, it is possible to expand the capability of the 3200 systems by modular expansion of central memory, at a cost of $55,000 per module. It is likely that the UMD 3200 (expanded) will become fully loaded during the five-year period. We would plan to install a new system and move the 3200 elsewhere, perhaps to St. Paul to establish a Group 1 facility there.

2. Group 3 Systems (Laboratory Instruction Systems) – We anticipate a need for two systems at a cost of about $250,000 each, one at $150,000 and one at $300,000.

3. Group 2 Systems – The statewide plan proposes a computer-assisted-learning system serving higher education as a whole and managed by the University. Separate from this instructional system is the need for a research and development system. Federal support for these CAL activities is declining; hence, if Minnesota decides to develop an instructional system, it may be necessary to also provide funding for the acquisition of the R and D system. The $200,000 is representative of systems that are being considered for the Center for Human Learning.

   The instructional programs for the Health Sciences Computer Center and for the Hybrid Laboratory will continue to grow. The present policy of providing some equipment support in these centers will continue to be valid.

4. Time-Sharing Systems – The statewide plan proposes the establishment of a time-sharing computing capability within higher education. The expansion of the system can be modular. The $450,000 over a three-year period would provide for approximately 100 terminals at the University.

In Table H.4.4 on the following page is summarized a tentative schedule. Both the cost estimates and the schedule itself will require much further planning. Its inclusion here is for purposes of illustrating where the University's instructional computing needs will likely develop and how the University's program can fit into a statewide program.

Table H.4.4. Summary of University Needs for Instructional Computing

(Dollars in Thousands)

	1971/ 1972	1972/ 1973	1973/ 1974	1974/ 1975	1975/ 1976
Peripheral Equipment for 6600	$ 230	$	$ 90	$	$
Remote Terminals	90	90	90	90	
3200 Expansion	55	55	55	55	
Laboratory Instruction Computers	300	300	300	350	
New General Purpose Computer Systems (or Expansion)				1,280	1,400
Computer Assisted Learning (R & D System)	200				
Other Group 2 (Equipment Support)			150		
Time-Shared Systems (University Portion of State System)	150	150	150		
Totals	$1,025	$595	$835	$1,775	$1,400

APPENDIX H.5

TABLES SUMMARIZING EXISTING (AUGUST 1970) COMPUTING FACILITIES AND PROGRAMS IN MINNESOTA HIGHER EDUCATION

Table H. 5. 1a. University of Minnesota Instructional and Research Computers

University of Minnesota	Hardware	Applications	Educational Uses 1969-70*: Computer Courses	No. of Students	Other Courses or Programs Using Computers	No. of Students	Shifts
General Facilities							
Central	CDC 6600 Configuration	Instruction & Research	57	3,715	93	5,900	2 (3 as needed)
West Bank	CDC 3200 Configuration	Instruction & Research	11	577	13	1,100	2 (3 as needed)
UMD	CDC 3200 Configuration	Instruction & Research	12	1,020	28	800	2 (plus weekends)
Hybrid Computer	EAI 680/CDC 1700	Instruction & Research	3	116	--	100	3
Health Sciences	CDC 3300 Configuration	Instruction & Research	13	120	--	250	3
St. Paul	IBM 360/30	Public Service and some Instruction	2	60	--	200	2
Several Departments	Time-Sharing Terminals Various Vendors	Instruction	--	--	76	3,700	
			98	5,608	210	12,050	

*Totals for Fall, Winter & Spring Quarters.

Table E. 5. 1b. University of Minnesota Administrative Computer

	Administrative Applications						Staff		Hardware	
University of Minnesota	Student	Fiscal	Personnel	Curriculum	Facilities	Property	Professional	Support	Configuration	Shifts Used
Number semi-permanent files less than or equal to number major Applications	36	44	20	4	3	2			IBM 360/50 384K, 2314 Disk (233 M Bytes) 4 tape drives 1600 BPI 9 track 1 tape drive 556 CPI 7 track 2702 Communications CTL Unit 2848 Local Communications CTL Unit 1231 Mark Reader 1403 Printer 1100/LPM 2549 Card Reader Punch 3 – 2260 Visual Terminals [illegible] Communication Terminals [illegible]2 – [illegible]y Punch & Verifiers 2 – 188 Collators 2 – 084 Sorters 2 – 557 Interpreters 2 – 519 Reproducers 1 – 047 Tape to Card Converter	130 hrs/wk

Table H. 5. 2. The State College System

State Colleges	Administrative Applications						Educational Uses				Staff		Hardware (Existing or, on order, May 1970)	
	Student	Fiscal	Personnel	Curriculum	Facilities	Property	Computer Courses	No. of Students	Other Courses or Programs Using Computers	No. of Students	Professional	Support	Configuration*	Shifts
Bemidji	9	2	3	1	2		6	167	4	375	1	3	1401 12k R, P, Pr 2 1311 Disc	1
Mankato	11	4	3		1	1	14	838	11	755	14	10	1620 20k R, P, Pr 1 1311 Disc 3 556 MT	2
													1130 16k R, P, Pr	2
Moorhead	24	12	1				3	282	7	477	2	3	1130, 16k R, P, Pr	1
													1620 60k R, P, Pr	1
St. Cloud	11						7	274	12	461	5	7	1620 20k R, P, Pr	1
													1401 12k R, P, Pr 2 55L MT 3 Disc	1-1/2
Winona	6				2		3	193	14	314	1	2	1130 8k R, P, Pr 1 Disc	1
Southwest	11	3					1	64	4	144	2	6	1130 8k R, P, Pr 2 2310 Disc	1-1/2

*R — Reader
P — Punch
Pr — Printer
MT — Magnetic Tape Transports
All equipment is IBM.

Table H.5.3. The State Junior College System

	Administrative Applications						Educational Uses				Staff		Hardware	
State Junior College	Student	Fiscal	Personnel	Curriculum	Facilities	Property	Computer Courses	No. of Students	Other Courses or Programs Using Computers	No. of Students	Professional	Support	Configuration	Shifts
Junior Colleges (17 Colleges)	60	17	24		1		2	90			1	3	IBM 1401 12k 2 MT 2001 556BPI 2 1311 Disc 1 1407	1-1/2
	Instructional use only						1	25	(For COBOL instruction at Lakewood)				IBM 360/30 Usage EDINET time-sharing system use; three ports and two WATS lines.	Three Active Terminals 8-12 hours per school day

Table H. 5. 4. The Private Colleges

	Administrative Applications						Educational Uses				Staff		Hardware	
	Student	Fiscal	Personnel	Curriculum	Facilities	Property	Computer Courses	No. of Students	Other Courses or Programs Using Computers	No. of Students	Professional	Support	Configuration	Shifts
Carleton	5	6							14		3	8	1401 8k, 1620 1 PDP 8/I 20k 2 Discs 2 Tapes 8 Terminals 3 PDP 8/L 8k 1 PDP 8/L 4k	1 1 1 1
Concordia* (St. Paul)	8	2											Uses St. Thomas Machine	
Golden Valley Lutheran		6											Uses Service Bureau Corp.	
Gustavus Adolphus	3									250	1/3		Time Share 360 G.E. Mark I, Mark II	22 hours weekly
St. Benedict	2	2			2		8						Uses St. John's 1620	
St. Johns	4	4								80	2		1620	1-1/2
St. Marys	9	9	2	2			1	5	7		12		1130 R, P, Pr	1-1/4
St. Olaf	5	5			1						2	3	1401	1
St. Teresa	3	1	1							100	3	3	1130	1-1/4

* These colleges have a joint project for development of college information systems.

Table H. 5. 4. The Private Colleges (Cont.)

Table H.5.4. The Private Colleges (Cont.)

	Administrative Applications						Educational Uses				Staff		Hardware	
	Student	Fiscal	Personnel	Curriculum	Facilities	Property	Computer Courses	No. of Students	Other Courses or Programs Using Computers	No. of Students	Professional	Support	Configuration	Shifts
St. Thomas*	3	2								150	2	4	CDC 160A 8k R, P, Pr 8 MT Rent Time on 6600 and 3300	1-1/2
Bethel*	2	2									2	5	Tab Equipment Outside Vendors	
Augsburg*											1	3		
Concordia** (Moorhead)													IBM 1620 P, Pr also some use of MSC and NSDU machinery	1
St. Catherine*							7		10					
Hamline*														
Macalester*													NRC 200 IBM 1130	1 1

* These colleges have a joint project for development of college information systems.
** This college is part of the Tri-College University.

R – Card Reader
Pr – Line Printer
P – Card Punch
MT – Magnetic Tape Transport

Table H.5.5. Area Vocational-Technical Schools

	Administrative Applications						Educational Uses				Staff		Hardware	
	Student	Fiscal	Personnel	Curriculum	Facilities	Property	Computer Courses	No. of Students	Other Courses or Programs Using Computers	No. of Students	Professional	Support	Configuration	Shifts
Alexandria	1	1			1		5	103					HW 200 System	
Austin							1	27					IBM 1130 CPU 1132 Printer 1442 Reader/Punch	47 hrs/week
Bemidji													IBM 1401	15 hrs/week
Duluth				1			12	201					IBM 1401 (School District)	
Hibbing						1	9	127					HW 200 System	
Mankato	1	1			1		12	232					IBM 360/25	1 shift/day
Minneapolis							27	453						
Moorhead	4						3	202	1	40			IBM 360/50 (NDSU)	
St. Cloud							6	91					RCA 501 for training Use Mankato 360/25	
St. Paul		1					20	809					IBM 1401 (School District)	
Willmar							6	294						

APPENDIX H.6

ANALYSIS OF GOALS AND THE COMPUTER RESOURCES NEEDED FOR MINNESOTA HIGHER EDUCATION

This appendix presents the detailed technical analysis which provided the results presented in Section 3 of the report. The primary role of this analysis was to yield quantitative estimates of the computer capacity required for instructional and administrative purposes in all five systems of higher education in Minnesota over the next ten years. These quantitative estimates of capacity are developed in terms of the three major hardware components of a computer system:

(1) Input/output or terminal capacity, in units of problems/student, terminals/student, or cards of input and lines of output per minute.

(2) Central processor capacity, in units of FORTRAN statements compiled per second and transactions per day, or the number of active time-shared terminals which can be supported.

(3) Mass storage (or secondary storage) capacity, in units of millions of characters.

1.0 EDUCATIONAL COMPUTING

The broad field of educational computing was factored into instructional computing for undergraduates, instructional computing for graduate students, and research computing.

1.1 INSTRUCTIONAL COMPUTING FOR UNDERGRADUATE STUDENTS

It is this kind of computing which is at present the most important for students in post-secondary institutions, and upon which the Pierce Report, Computers in Higher Education (1) and the General Learning Corporation study, A Feasibility Study of a Central Computer Facility for an Educational System (7) are based. For undergraduates, the analysis here will follow the methods and assumptions of these two earlier reports, but based on data for higher education in Minnesota rather than on national data (1) or a hypothetical school system (7). The Pierce Report and the General Learning study both excluded graduate education from explicit consideration. In Section 1.1.5 of this appendix, the specific needs of that form of advanced education are considered.

The first step is to classify the various academic areas of study according to whether they involve "substantial" (S), "limited" (L), or "casual" (C) use of computers. These three usage categories are defined in terms of the number of courses requiring computer use and the number of problems assigned per course, as shown in Table H.6.1. In Table H.6.2, the major areas of study (Office of Education classifications) are classified according to the degree of computer usage which they require. The first column here is taken directly from the Pierce Report, based on baccalaureate degrees granted in 1963-64. The remaining columns give similar information for baccalaureate-degree-granting institutions in Minnesota, 1968-69. Rounding off the percentages of Minnesota graduates in each of the three usage categories leads to a pattern of 30% substantial / 45% limited / 25% casual usage needs within the state. This pattern is close to the Pierce Report estimate (35%/40%/25%) and will be used in the analysis for all degree-granting institutions in the state. Consultation with many college and university faculty and administrators, both in Minnesota and elsewhere in the nation, have confirmed the reasonableness of the Pierce Committee's estimates of the need for computing in higher education.

The needs of the area vocational-technical schools and the state junior colleges cannot be analyzed in quite the same way. On the basis of substantial experience at several of the area schools, their needs can be summarized as in Table H.6.3a, in terms of the programs they offer and the amount of access required either to a small business-oriented computer, or to a medium-speed (100-200 cards per minute and 200-300 lines per minute) card reader-line printer terminal.

The scale in Table H.6.3a provides approximately two hours per day of terminal time to schools with one-year accounting programs, four to six hours per day to those with two-year accounting programs or small data processing programs, and eight or more hours to those with sizable programs in data processing. In addition, it will be assumed later that schools with data processing enrollments over 100 may possess a small computer.

For the junior colleges, we have taken Fall 1969 enrollment data from a typical Minnesota junior college, and determined the fraction of total enrollment in courses in which computers should play a role – that is, substantive courses with some quantitative content in those areas of Table H.6.2

requiring substantial or limited computer usage. The results of these estimates are summarized in Table H.6.3b, with the average number of time-shared terminal hours and numbers of assigned problems per year computed from the Pierce Report's estimate of ten hours of time-shared terminal time per student enrolled in S-- or L--class introductory-level courses.

Because of the differences in the kinds of programs offered at the area schools and junior colleges, their computing needs will be analyzed separately from those of the degree-granting colleges. In applying the results from Tables H.6.2 or H.6.3b, it must be kept in mind that they represent averages over a class of students: although a student enrolled in a course in descriptive biology may use a computer not at all, another student in a beginning genetics course may use it twice as much as the typical "substantial" user.

Two more pieces of information must be derived before the analysis can be completed. First, by averaging the number of problems per academic year (Table H.6.1) over the three usage categories, weighted according to the fraction of students in each category (Table H.6.2), we calculate

11.3 problems per student per academic year

assigned on the computer. Secondly, assuming (14 hours/school day) x (200 school days/year) x (80% available time on the computer), there are

2,240 available computing hours/academic year

These assumptions are rather optimistic for a real school environment; they have been taken from the General Learning Corporation study (7). Now the estimates so far developed can be used to estimate the computing load for both a time-shared computing system (TS) using inexpensive low-speed terminals, and a remote-job-entry system (RJE) using a much smaller number of medium-speed terminals.

1.1.1 A Time-Shared Computer System

A time-shared computer system is defined in Section 3 of the report in terms of the user to include the following necessary and sufficient characteristics:

(1) Input and output through a keyboard-printer terminal operating at between 10 and 30 characters/second maximum. (The lower speed is the most common in 1970.)

(2) Capability for the user to interact with a program during its execution.

(3) Response time of five seconds or less to a request not requiring excessive computation.

The capacity of a time-shared computer system is measured in terms of the number of active terminals. Assuming that students in the substantial usage category are more expert than those in the limited usage category, and these in turn more skilled than the casual users, the estimates of terminal hours per problem in Table H.6.4 can be extracted from the General Learning Corporation study (7). Averaging the results in Tables H.6.1, H.6.2, and H.6.4 over the three usage categories and dividing by 2,240 available hours per academic year results in

6.67 time-shared terminals per 1,000 students, or
150 students per time-shared terminal

This is the required terminal capacity for a time-shared instructional computing system in a degree-granting college or university. Applying the same reasoning to the junior college data in Table H.6.3b results in

3 TS terminals per 1,000 junior college students, or
333 junior college students per TS terminal

Because the training in vocational schools is largely devoted to business data processing and related applications, for which low-speed time-shared computer terminals are not appropriate, their needs have not been estimated in these terms.

The dedicated computer capacity necessary to serve a given number of low-speed time-shared terminals can best be estimated in exactly those units — number of active terminals serviced. Over the past several years, experience with several time-sharing systems of various sizes and costs has shown how many active terminals they can service adequately. (The industry standard for adequate service is evolving to a maximum response time of about five seconds for an input request which does not involve extensive computing.)

For a system which handles time-sharing and remote-job-entry and other batch computing, the computer capacity required for the two kinds of work must be compared. The General Learning Corporation study (7) provides reasonable estimates for this purpose: an average of one request per active terminal every thirty seconds, with the equivalent of fifteen FORTRAN statements compiled per request and a factor of two to accomodate peak loads, leads to the peak load compiling rate required:

6.67 statements per second per 1,000 4-year college students

3 statements per second for 1,000 2-year college students

This can be folded in with similar estimates for a RJE system given below.

Finally, the mass storage capacity of a TS system must be estimated. Relying this time on experience at the University of Minnesota as well as on the General Learning Corporation study, each active user needs an average of 3,000 characters of storage for his own programs and data. An average of the number of courses using the computer (from Table H.6.1, weighted by the usage factors in Table H.6.2), leads to a figure of about 40% of the total students in a college using the computer at any one time. Hence,

1.2 million characters per 1,000 students at 4-year colleges

600 thousand characters per 1,000 students at 2-year colleges

of mass storage is required. Other mass storage requirements in a time-shared computing system are a function of the system design itself, and will not be specified in detail.

1.1.2 A Remote-Job-Entry Computer System

Instructional computing needs can also be satisfied by a computer system operating in the batch-processing mode, with remote (or local) terminals for entering programs and data, and for receiving and printing the output. An analysis of the input/output (or RJE terminal) capacity needed for this mode of operation is outlined in Tables H.6.5 and H.6.6, which again are patterned after the study done by the General Learning Corporation (7). Two kinds of programming languages are assumed to be available; a simple language such as BASIC, and a more advanced language such as FORTRAN. The proportions of students using these languages will differ in lower division and upper division, as shown in Table H.6.6. Despite these differences, the average number of characters of input or output per student per academic year or per minute (2,240 available hours per academic year) comes out almost the same for lower and upper-division students. Assuming medium-speed RJE terminals with input rates of 300 cards/minute and line printer output rates of 300 lines/minute, (input and output not functioning at the same time), the total number of terminals required to serve 1,000 students may be calculated quite readily as

$$0.476 \simeq 0.5 \text{ RJE terminals/1,000 students 4 yr college}$$

Carrying out a similar analysis for the more limited needs of students at junior colleges yields

$$0.16 \text{ RJE terminal/1,000 junior college students}$$

The obvious implication of this figure is that even a single RJE terminal has substantially more capacity than the largest Minnesota junior college needs for instructional computing.

The computer capacity needed to service these terminals can be estimated from the data above. From Tables H.6.5 and H.6.6, it is possible to calculate that there will be about 0.4 computer runs per 1,000 students per minute. Assuming that there are an average of seventy statements to be compiled on each run, that every third run requires execution of the program, that execution of a compiled program takes about 75% as long as the compiling, and a factor of two to accommodate peak loads, then the computer capacity required is:

$$1.2 \text{ compiled statements per 1,000 4-year college students/second}$$

$$0.4 \text{ compiled statements per 1,000 2-year college students/second}$$

This is not a rate at which the computer must operate continuously fourteen hours per day in order to process the entire instructional computing load; it is the rate at which the computer must be capable of processing student jobs to avoid queuing and job turn-around delays long enough to seriously affect the educational effectiveness of the computer.

Users of a remote-job-entry or other batch-processing system do not, in general, require on-line mass storage as do time-sharing users. Their mass storage needs are taken care of by the punched (or mark-sense) cards they use for input purposes. The computer systems considered in the next section of this report will be configured with adequate mass storage capacity to support a workable remote-job-entry batch-processing operation with several programming languages, and utility and applications program storage.

Another way to furnish remote-job-entry computing is via low-speed terminals (10 characters/second, the same as used for time-sharing) rather than medium-speed card reader-line printer devices. Although it is rather inconvenient for students to work with punched paper tape as an input medium from a simple teletype terminal, it can be done. Mark-sense card readers may also be attached to such terminals, greatly increasing their convenience to students (and, of course, adding to the cost).

An analysis in terms of student input/output rate shows that about 20 low-speed terminals would be equivalent to one medium-speed terminal; this ratio is approximately equal to the 2,400/110 ratio of transmission speeds. In terms of computing capacity, the same amount will be needed for remote-job-entry regardless of the speed of the terminals used. The economic and pedagogical tradeoffs between low and medium-speed remote-job-entry and time-sharing are discussed in Appendix H.8.

1.1.3 A Mixed Time-Shared/Remote Job Entry System

Estimating the input/output and computer capacities for an instructional system mixing the two modes of computing is much more difficult – the General Learning Corporation study, for instance, simply did not try to do it. However, because the regional computer center being established at Mankato State College is considering mixed-mode operation, we will attempt an estimate.

First, in terms of input/output capacity, the figures 6.67 TS terminals or 0.5 RJE terminals per thousand students imply that:

I/O: 13.3 TS terminals are about the equivalent of 1 RJE terminal

In terms of the computer or compiling capacity itself, we will make the reasonable assumption that the swapping of programs in and out of the computer in time-shared operations will add about 30% to compiling load on the computer. (This assumption is valid when the TS computer is loaded near its capacity, so that swapping takes a large fraction of the computer time. When the system is running far under its capacity, the swapping will have little effect.) On this basis, the mixed mode compiling requirements are:

Capacity:	1.2 Statements per sec per 1,000 RJE students
and	8.8 Statements per sec per 1,000 TS students

In other words, it requires about seven times the raw computer compiling power to service 1,000 students in a time-shared mode compared to a batch-processing mode. This suggests that the time-shared component of mixed-mode computing is not very efficient, which is known to be the case. The same statement, however, may not apply to the comparison of a dedicated instructional time-shared computer with a batch-processing system. Large computing programs in advanced languages should not be handled on a time-shared basis. Programs of this kind occur less frequently in an instructional setting, particularly at the lower division level, than they do in business, industry, or research. When they do occur, they can and should be diverted to a batch-processing system. A small or medium sized computer dedicated to time-shared computing for small jobs may therefore be rather more efficient and less expensive than the above factor of seven would imply. It is certainly true that the operating system associated with a good small time-shared computer makes it more efficient than the same computer operated in a hands-on batch mode.

1.2 INSTRUCTIONAL COMPUTING FOR GRADUATE STUDENTS

The analyses in the Pierce Report and the General Learning Corporation study (References 1 and 7), and so far in this appendix, are directed to the computing needs of institutions which offer primarily undergraduate programs. As such, they suffice for all of the institutions in Minnesota except the Twin Cities campus of the University of Minnesota. The state colleges and the Duluth campus of the University all have small graduate programs comprising a few percent of total enrollment, and concentrated largely in areas which do not make excessive demands on computing. Much of the instructional computing associated with these graduate programs will be course-related rather than large thesis research calculations. As such, it appropriately may be lumped together with undergraduate instructional computing.

It has been the policy of the state to concentrate most of the graduate instruction — particularly the expensive, research-based programs in engineering and the physical, social, and life sciences which require quite substantial amounts of computing today — on the Twin Cities campus of the University. In 1969-70, about 20% of the total enrollment on this campus was in graduate programs (not including first-professional training), and this is expected to rise to about 26% by 1980. The information on computer utilization at the University in 1969-70 (see Appendix H.4) shows that graduate students consume a substantial amount of computing capacity not specifically related to their course work.

Using the data from Appendix H.4 on university computer utilization for 1967-70, plus enrollment data summarized in Appendix H.10, it is possible to show that, in terms of the computer capacity they require:

$$(1{,}000 \text{ graduate students}) \simeq 3.5 \times (1{,}000 \text{ FTE undergraduate students})$$

In arriving at this ratio, it was necessary to use total enrollment figures for the graduate students rather than full-time-equivalents, because the number of course credits associated with full-time graduate study is considerably less than the 15 assumed for undergraduates. Furthermore, the first-level professional students have been lumped with undergraduates, because most of their computing will be course-related, as it is at the undergraduate level. More advanced professional students function as graduate students in their professional field, with most of their computing related to thesis research, as is the case for graduate students. The ratio of 3.5 between per-student graduate and undergraduate computing needs will be used, together with the enrollment projections summarized in Appendix H.10, to estimate the total needs of the University of Minnesota for instruction-related computing.

The data processing, computer programming, and computer science programs and courses in all of the systems of higher education provide specific vocational training for their students. The general requirements of these courses and programs have been included in the analysis of the previous section, along with the specific requirements of computer training in the vocational schools. The entries in Table 3.1 for the area schools are based on 1974-75 enrollment projections in accounting and data processing from the State Department of Education. These presume that the 11 existing data processing programs will be increased to 13 by 1974-75, with enrollments ranging from 25 to 150. There seems to be some disagreement, both among vocational school faculty and the businessmen who make up the Data Processing Committee of the State Board of Vocational Education, as to whether these are more data processing curricula than the state needs, or whether the need for geographical distribution of opportunities for post-secondary training requires this number. This issue is addressed in the recommendations in Section 5. For the analysis here, the present projections of the State Department of Education have been assumed.

Special computer equipment required for other special training programs, such as the Computer, Information, and Control Sciences Department at the University of Minnesota, is far too important to ignore. These needs do not lend themselves to the kind of analysis carried out here, but they have been included in the recommendations of Section 5.

1.3 RESEARCH COMPUTING

The two systems of higher education which have a defined mission in research and graduate training are the University of Minnesota and to a lesser extent, the state colleges. As the state's major resource for graduate training and research, the University has the largest need and greatest capacity for research computation. In Section 1.2 of the main report, it was pointed out that research computing facilities can be placed in three classes:

(1) general-purpose computers;

(2) general-purpose computers configured for and dedicated to specific application areas which occupy them almost full-time; and

(3) special-purpose computing devices (usually small) built into laboratory apparatus as part of the equipment.

The second and third of these classes will not be considered further, since they are supported almost exclusively by funds from outside grants and contracts, and receive university support only in very limited amounts and under the same type of conditions prevailing for other kinds of university research support. General-purpose research computing services are necessary for many of the research activities conducted in large universities. The computer capacity required to provide these services at the University of Minnesota will be identified as excess capacity over and above the instructional computing needs. From Appendix H.4, it is clear that about half of the activity on a large university computer is for research and public service applications. Since much of this computing is funded from outside sources, it will not be considered in more quantitative detail than this: the service capacity must be there, but it does not take the major investment of state funds which is necessary to support instructional computing.

2.0 ADMINISTRATIVE DATA PROCESSING

The role of administrative data processing in higher education is defined in Section 3 of the full report. As mentioned there, the analysis of the computer capacity required to process administrative data in Minnesota higher education has been based on the administrative applications developed or planned for the University of Minnesota, which has the most extensive system of this kind in the State.

The resulting estimates of needed data processing capacity are summarized in Table H.6.7 of this appendix. Details of the administrative data processing capacity analysis, complete with annotations on the various assumptions made in scaling the results to the different institutions, may be found in Table H.6.8. Summaries of the total capacity estimates for 1969-70, 1975-76, and 1980-81 appear in Table 3.2 of the report. The overall capacity results are assumed to scale within a system of institutions and with time according to the total enrollment. From an examination of Table H.6.8, it will be seen that several other more relevant factors are used to scale various data file sizes or applications capacities. All of these factors, however, increase and decrease with headcount, making this a reasonable, if not precise, quantity by which to scale. To facilitate scaling of the individual private colleges and state colleges, the figures are given in the tables in terms of a private college with 1,000 students (a typical size) and a state college with 10,000 students (between Mankato and St. Cloud in size in 1969-70).

As noted in Table H.6.8, several of the files and applications have not (yet) been implemented at the University, although most of these are in the thinking and talking stage, at least. The one major exception is student registration, utilizing a curricula file. To estimate the input/output, transaction, and mass storage capacities required for this type of application, a crude system design was constructed, which is adequate for capacity estimates but not as the basis of a working system design.

Input/output capacity is assumed to be accommodated by high-speed card readers (1000 cards/minute) and line printers (1,000 lines/minute) located at the computer site. In addition to these production facilities, there are two other kinds of I/O devices which bear mention. The central offices for the State College and State Junior College systems require access to information in the data bases stored on computers which will be located at colleges. They may also need some processing of the information to meet their special reporting needs. Similarly, the Higher Education Coordinating Commission has needs for information and processing. Each of these three groups should therefore have access to a medium-speed remote-job-entry terminal. Since they are all located in the Capitol Square Building in St. Paul, and if the statewide common communications interface is implemented, then all three organizations can share a single terminal. The State College Board already has such a terminal on order for installation when the Mankato computer is installed. It is anticipated that they will make this terminal available also to the State Junior College Board and the Higher Education Coordinating Commission, when those two organizations are in a position to use it.

The second kind of input/output device which is implied for effective use of an administrative data processing system is a query terminal — a cathode-ray-tube-display-keyboard or teletypewriter-like terminal for rapid retrieval of certain kinds of information from the system. Estimates of query terminal needs for student registration are included in Table 3.2 in the report. Several terminals of this kind are being installed in various administrative offices at the University and at Macalester College. One can see a need for a few of them at each state college and one at each state junior college, linking the junior college president to the remotely-located computer data base. When the data bases are available for their use, the software designed, and the hardware and communications specified, then these institutions should make requests to fund suitable query terminals. When such on-line terminals are in use, it will be most important for the data systems manager to provide excellent maintenance (updating) of the data bases: bad or old information may be worse than no information at all.

Table H.6.1. Definition of the Three Pierce Report (1) Categories of Computer Use by College Students

	Substantial	Limited	Casual
No. courses requiring computer use	10	4	3
No. problems assigned per course	12	6	3
Total No. problems in 4 yrs.	120	24	9
Average No. problems per academic yr.	30	6	2.3

Table H.6.2. Classification of Computing Needs by Major Area of Study, Based on Bachelor's Degrees Conferred

Major Area of Study	National Usage 1963-64* Substantial S (%)	Limited L (%)	Casual C (%)	University of Minnesota 1968-69** S (%)	L (%)	C (%)	Minnesota State Colleges 1968-69** S (%)	L (%)	C (%)	Minnesota Private Colleges 1968-69** S (%)	L (%)	C (%)	Total Minnesota Colleges 1968-69** S (%)	L (%)	C (%)
Agriculture			1.0			2.6									1.0
Biological Sciences	5.0			5.7			2.8			7.0			5.2		
Business & Commerce	6.1	6.1		4.1	4.0		7.1	7.1		2.5	2.5		4.6	4.5	
Education		18.3	6.1		19.1	5.5		33.3	9.7		15.0	4.3		23.5	6.5
Engineering	7.2			8.0			0.6						3.3		
English & Journalism			7.6			5.3			5.9			10.3			7.0
Fine & Applied Arts			3.5			3.0			2.8			5.7			3.7
Foreign Lang. & Literature			2.6			1.9			1.7			4.9			2.7
Health Professions	0.2	2.3		0.4	4.1		0.1	1.1		0.5	5.0		0.4	3.4	
Home Economics			1.1			1.6			0.1			0.5			0.8
Mathematical Sciences	2.1	2.0		1.3	1.2		2.8	2.7		2.1	2.0		2.0	2.0	
Philosophy			1.0			0.6			0.1			1.7		1.0	
Physical Sciences	3.8			2.6			1.7			4.3			2.9		
Psychology	1.5	1.4		2.4	2.3		1.1	1.1		2.4	2.4		2.0	1.9	
Religion			0.8			0.1						2.9			0.9
Social Sciences	8.3	8.3		9.1	9.0		7.9	7.8		11.2	11.2		9.3	9.3	
Other	0.6	0.7	2.6			6.0			1.8			1.4			3.3
TOTALS	34.8%	39.1%	26.3%	33.6%	39.7%	26.6%	24.1%	53.6%	22.1%	30.0%	38.1%	31.7%	29.5%	42.6%	26.9%

* U.S. Office Education, quoted in the Pierce Report, Computers in Higher Education (1).
** Minnesota Higher Education Coordinating Commission, Survey of Institutional Information for Minnesota Colleges and Universities (April 1970).

Table H.6.3. Computing Needs of Two-Year Post-Secondary Institutions in Minnesota

a. Area vocational-technical schools.

(Enrollment in data processing plus 50% of enrollment in accounting)	Hours per school day of terminal or computer time needed
less than 25	2 hrs.
25-50	4
50-75	6
75-100	8
greater than 100	12

b. State junior colleges. Calculated from 1969-70 course enrollment data from Anoka-Ramsey State Junior College.

Average number of students enrolled per quarter in courses requiring significant computer use	1,469
Average number of FTE students per quarter	1,654
Hours of time-shared Terminal time required per student (Pierce Report ( ))	33.3 hrs.
Arbitrary reduction for students enrolled in more than one course using computers	0.75
Average number of terminal hrs. per FTE student	2.25

Table H.6.4. Time-Shared Terminal Hours Per Problem, By Category of Usage for College Students

	Substantial	Limited	Casual
Terminal sessions/problem	2	3	4
Terminal hrs./session	0.55	0.5	0.45
Terminal hrs./problem	1.1	1.5	1.8

Table H.6.5. Input/Output Requirements Per Student Problem, in Characters Per Problem

Programming Language	Runs Per Problem	Average Source Program Length Input/Run	Object Language Multiplier	Average Object Program Length Output/Run	Total Characters Per Problem	
					INPUT	OUTPUT
Simple	3	1,400 char.	8	11,200 char.	4,200	33,600
Advanced	6	2,800 char.	5	14,000 char.	16,800	84,000

Table H.6.6. Input/Output Requirements Per 1,000 Lower Division and Upper Division College Students (Assuming an average of 11.3 problems per student per academic year, and 2,240 available hours per academic year.)

	Fraction of Problems in Program Language		Runs Per Student in Program Language		Total Runs Per Student	INPUT		OUTPUT	
	Simple	Advanced	Simple	Advanced		Characters Per Student	Cards Per Min.	Characters Per Student	Lines Per Min.
Lower Div.	0.4	0.6	13.6	40.7	54.2	0.99	33.0	5.4	108
Upper Div.	0.3	0.7	10.2	47.5	57.9	1.01	33.4	5.8	116
					AVERAGE		33.0		110

Table H.6.7. Summary of Need Estimates for Data Processing Capacity in Minnesota Colleges

College or System	Input Cards or Entries*	Lines of Output*	Computer Transactions*	Mass Storage**
Univ. of Minnesota 1969 (50,000 students)	7.4	46.9	105.6	660
A State College with 10,000 students	1.16	6.26	13.4	87
State College System 1969 (37,681 students)	4.35	23.6	50.4	328
A Jr. College System with 20,000 students	2.1	11.6	22.7	140
State Jr. College Sys. 1969 (17,544 students)	1.84	10.2	19.9	123
A Private College with 1,000 students	0.11	0.57	1.84	11
Total Minnesota Private Colleges, 1969 (27,137 students)	2.9	15.4	50.0	400

* Figures are stated in millions per year.
** Millions of characters.

ERIC User please note:

Chart from original document is not reproduced here due to small print size.

Chart showed for the University of Minnesota, for State and private institutions of various sizes data volume (in terms of input cards, output lines, computer transactions, and file size for such areas as Student Files, Staff and Payroll, Courses and Curricula, Space, and Property Inventory.

APPENDIX H.7

TABLES SUMMARIZING HARDWARE AND COMMUNICATIONS FACILITIES AND THEIR COSTS

Table H. 7. 1. A Scale of Computer System Capacities and Costs

a. Computer Systems Suitable for Batch-Processing and Support of Medium-Speed and Low-Speed Remote Terminals.

Class	Computing Speed: FORTRAN Statements Compiled Per Min. (thousands)	Computing Speed: Data Processing Transactions/Min. (thousands)	Approx. Monthly Lease Cost	Examples
A.	25 (10 - 25)	8 - 12	$180,000	CDC 7600 IBM 360/195 B 8500 U 1110
B.	12 (12 - 20)	8	85,000	CDC 6600
C.	6 (5 - 7)	7 (5 - 9)	65,000	IBM 360/75 U 1108 GE 645 B 6500
D.	3 (2 - 4)	5.5 (4 - 7)	40,000	IBM 360/65 U 1106 GE 625 CDC 3500 H 8200
E.	2 (1 - 3)	2.5 (1 - 4)	25,000	CDC 3300 IBM 360/50 B 5500 XDS 940
F.	1	0.8 (0.5 - 0.1)	12,000	IBM 360/40 U 9400 CDC 3200
G.	0.7	0.25 (0.15 - 0.3)	8,000	IBM 360/30 U 9300 CDC 3150
H.	0.350	0.1 (0.5 - 0.15)	4,000	IBM 360/25 CDC 1700 H 120
I.	N/A	Approx. 0.5	2,000	IBM 360/20 IBM 1130 9200 PDP-8

Table H. 7. 1. A Scale of Computer System Capacities and Costs (Cont.)

b. Time-Shared Computer Systems.

Class	No. Active Terminals Supported	Approximate Cost: Purchase (thousands)	Approximate Cost: Monthly Lease (thousands)	Approximate Cost: Purchase Per Terminal	Cost Per Per Month Terminal	Examples
Z.	16 to 40	$100 to $300	$2.5 to $7.5	$4,000 to $8,000	$100 to $200	HP 2000 A HP 2000 B GE 255 PDP-8
Y.	40 to 60	$300 to $600	$7.5 to $15	$8,000 to $12,000	$200 to $300	CDC 3300 H 1648 PDP-10 IBM 360/44
X.	40 to 120	$500 to $2,500	$12.5 to $62	$12,000 to $16,000	$300 to $400	XDS 940 SIGMA 7 GE 435 GE 635 B 5500
W.	60 to 200	$2,500 and up	$62 and up	Over $16,000	Over $400	CDC 6600 (KRONOS) IBM 360/67 U 1108

Information gathered from:

a. "Evolving Computer Performance – 1963-1967", in Datamation, Jan. 1968.

b. Auerbach Computer Notebook International, Volume 1.

c. "Characteristics of General-Purpose Digital Computers", in Computers and Automation, June 1968.

d. "Computer Characteristics", in Business Automation, September 1967.

e. "Time-Sharing Services", in Modern Data, February 1970.

Table H. 7. 2. Mass Storage Monthly Costs*

Type	Cost Per Month: Control Unit	Cost Per Month: Storage Unit	Storage Volume (Million of Characters)	Dollars Per Month Per Million Characters
IBM 2311		$ 570	7.25	$ 80.70
2841 (2311 Controller, 1x8)	$ 525			
IBM 2312		535	29	24.80
IBM 2318		920	58	19.00
IBM 2313		1745	117	16.50
2314 (Controller, 1x8)	1480			
CDC 841-3 (3 access mechanisms)		1865	107	21.60
CDC 841-8 (8 access mechanisms)		4150	286	16.90
CDC 821-1 (1 access mechanism)		2750	419	6.30
CDC 821-2 (2 access mechanisms)		5100	838	6.30
3533 (controller for 8 access mechanisms)	700			
UNIVAC FASTRAND II	1280	4265	144	30.70
Burroughs				
17 MS series	included	450	2	225.00
23 MS series	50	4950	100	50.00
incremental		900	20	45.00
40 MS series	50	3950	100	40.00
incremental		700	20	35.00
60 MS series	50	2700	100	27.50
incremental		450	20	22.50

*Obtained from sales offices.

Table H. 7. 3. Mass Storage Costs for Minnesota Institutions of Higher Education in 1975.

System	Storage Type*	Storage Requirement (Millions of Characters)	Monthly Rate Per Million Characters	Monthly Cost**
University of Minnesota	2313 (IBM)	827	$16.50	$ 5,460
Twin Cities				
Duluth	841-3(CDC)	45	21.60	388
Morris				
Waseca				
State Colleges	(U)FASTRAND II	426	30.70	5,230
Bemidji	2311 (IBM)	51	80.70	1,646
Mankato	(U)FASTRAND II	131	30.70	1,615
Moorhead	2311 (IBM)	61	80.70	1,958
St. Cloud	(U)FASTRAND II	105	30.70	1,290
Southwest	2311 (IBM)	37	80.70	1,282
Winona	2311 (IBM)	41	80.70	1,323
State Junior College System	2313 (IBM)	204	16.50	1,333
Private Colleges	2311 (IBM)	490	80.70	15,817
Typical	2311 (IBM)	11	80.70	354

* Depends on computer installed or planned as well as storage requirements.
** Assumes that 40% of required storage will be on-line at one time.

Table H. 7. 4. A Scale of Representative Remote Terminal Characteristics and Costs

Class	Characteristics	Approximate Average Cost		Examples
		Purchase	Monthly	
h.	Small computer, 4-8K memory, FORTRAN and/or COBOL compiler, 4 tape drives or discs, medium speed line printer, card reader and card punch.	$160,000	$4,000	IBM 360/25 CDC 1700 H 120 GE 115 B 500 U 9300
i.	Mini-computer, 4-8K memory. Some have FORTRAN compiler. Low speed tapes, small disc, or multi-function card machine. Low speed printer.	90,000	2,500	IBM 360/20 U 9200 IBM 1130 DEC PDP-8 CDC-8090
j.	RJE terminal with card reader input and printer output. Can be programmed to some extent for off-line, either by plug-board or limited instruction set.	60,000	1,500	ASC 1170/3
k.	Simple RJE terminal with card input and printer output. Some have hard-wired feature for off-line listing of cards.	32,000	800	CDC 200 UT IBM 2780 DATA 100 70-1 UNIVAC DCT 2000
l.	Remote CRT (video) terminals with keyboard entry. Teletype replacement. No hard copy (display only). Some are buffered. Features and options vary. Price of modems not included.	4,000	135	INFDTON DATA 100 73 DATAPOINT 3300 HAZELTINE 2000 LOGITRON L/1 VIDEO SYSTEMS VST/500
m.	Keyboard terminals, 10-30 char/sec, with punched paper tape input.	1,000-4,000	60-100	ASR 33 (TELETYPE FRIDEN 7100 UNIVAC DCT-500 DURA 1051 IBM 2741
n.	Low-speed mark-sense card or document reader (input only) for use with a keyboard-printer or display terminal. Speed is limited to that of the device through which it is connected.	3,000-4,000	100-125	HEWLETT-PACKARD 2760A MOTOROLA

Information gathered from:

a. Auerbach Computer Notebook International, Volume 1.
b. Small Digital Computers, in EEE, February 1970
c. "Data Communication Terminals", in Business Automation, September 1969.
d. "Characteristics of General-Purpose Digital Computers", in Computers and Automation, June 1968.
e. "Low-Cost CRT Terminals", in Datamation, June 1968.
f. "Interactive CRT Display Terminals", in Modern Data, June 1970.
g. "Computer Characteristics", in Business Automation, September 1967.

Table H.7.5. Characteristics and Costs of Some Available Multiplexors.*

Type and Speed of Terminals	Maximum Number of Terminals	Other Characteristics	Typical Cost: Monthly Lease	Typical Cost: Purchase	Manufacturer and Model
TTY Type (110 bps) Full Duplex	4 per node	For multidrop configurations (modem included)	$64	$2000	ADS 680
	16 total	Terminator for system of ADS 680's (modem included)	$95 at termination	$2800	ADS 680T
TTY Type Full Duplex	23	One needed at each end end of line (modem needed at each end)	$291 per end	$5950 per end	ICC (MILGO) MC-70
TTY Type (150 bps) Full Duplex	36	One needed at each end of line (modem needed at each end)	$200 per end	$5875	ADS 660
TTY over 150 bps lines Half Duplex	accepts 24	Inputs to 1A data set as modem (on terminal end only)	$85 per end	--	Bell System 10A concentrator
	8	Modem for use with 10A concentrator (one on each end)	$225	--	Bell System 1A Data Set

*Obtained from sales literature or sales offices.

Table H. 7. 6. Characteristics and Costs of Available Modems*

This list is not representative of all manufacturers or models on the market.

Transmission Rate (bits/sec.)	Other Characteristics	Typical Cost (per end)		Manufacturer and Model
		Lease Per Mo.	Purchase	
2000	Dial-up line	$ 73	-	Bell 201A
2400	Conditioned private line	73	-	Bell 201B
2400	Dial-up line	90	$2400	Rixon PM-24A
2400	Unconditioned private line	93	2750	ADS
2400 & 4 low speed channels	Unconditioned private line. Allows 4 teletype channels, simultaneously with 2400 bps RJE Terminal	175	5500	ICC (MILGO) 4400/24PB
4800 (Two 2400 channels)	Conditioned private line	200	5800	ADS 448
3600	Dial-up	207	-	Bell 203
3600	Dial-up	220	5800	ICC (MILGO) 3300/36

* Obtained from sales literature or sales offices.

Table H.7.7. Some Common-Carrier Communication Line Services and Costs*

Type of Service	Characteristics	Monthly Cost	Company
Leased Voice-Grade Lines	Private line, 2000 bits-per-sec	$4/mi	Bell
G.S.A. Lines	Same as above but using lines of federal government with volume discount rates. Available only between certain locations	$0.62/mi	Bell
INWATS	Unlimited number of incoming calls from within the state	$590	Bell
OUTWATS	Unlimited number of outgoing calls to points within the state	$590	Bell
Dial-up	Long-distance over regular phone network, within Minnesota	$6/hr (night) $20/hr (days)	Bell
C2 Line Conditioning	Allows higher-speed data transmission over same lines	$17 per end	Bell
Leased Low Speed Lines	150 bits per second	$2/mi	Bell

* From Northwestern Bell Telephone Company

Table H. 7. 8. Existing Leased Tie-Lines to the State Office Complex in St. Paul.

*Brainerd	*Marshall
Crookston (one-way out)	*Moorhead
**Duluth	*Rochester
*Fergus Falls	**St. Cloud
Grand Rapids	Thief River Falls (one-way out)
Hibbing	Virginia
*Mankato	*Willmar
	Winona

* An OUTWATS line also available in these cities.
** Two OUTWATS lines available.

Table H. 7. 9a. Approximate Costs Per Line for Front-End Computers Dedicated to Communication Control

No. of Lines	Cost Per Low-Speed Line		Cost Per Medium-Speed Line	
	Purchase	Monthly	Purchase	Monthly
8			7, 750	267
16	3, 875	133	6, 318	209
32	3, 159	104	4, 250	140
64	2, 125	70	3, 450	111
128	1, 725	56	2, 948	94
256	1, 474	47		

NOTE: This class of equipment can be (1) a small or mini-computer with a multiplexor, or (2) a computer de-designed specially for communications control, such as COMCET. Typical equipment of the latter group is shown in Table H. 7. 9b.

Furthermore, the cost per line can vary considerably depending on such factors as memory size, number and type of peripherals.

Sources:

1. "External Control", Datamation, September 1970
2. Control Data Corporation
3. COMCET
4. Auerbach Minicomputer Notebook

Table H.7.9b. Characteristics and Costs of a Few Communications Controllers. (This list is not representative of all manufacturers or models available.)

Lines Accommodated		Computer for Which Designed	Other Characteristics	Typical Cost		Manufacturer and Model Number
Number	Speed (bps)			Purchase	Monthly	
64 - to - 2,048	"all speed" - to - low speed	IBM 360 UNIVAC 1108	32K-262K byte memory, 900 ns 32 bit word 16 GPR's	$175,000 to $250,000	$ 4,300 to $ 6,300	COMCET 60
32 and up	75 230,400	IBM 360 UNIVAC 1108	32 bit cpu 32-132K bytes	$125,000 to $200,000	$ 3,200 to $ 5,200	COMCET 40
4[illegible]	110-150	COMCET 60/40		$ 15,000 to $ 20,000	$ 416 to $ 555	COMCET 10
125 - to - 250	200 - to - 30-300		8-64K word memory, 100 instructions	$ 50,000+	$ 1,500 to $20,000	G.E. DATANET 500
2 - to - 128	50,000 - to - 110-150	IBM 360 IBM 1130 SIGMA CDC 3000 CDC 6000	8-32K bytes 900 ns	$ 25,000 and up	$ 694	COMPUTER COMMUNICATIONS CC-70

Source: 1. COMCET
2. Datamation, New Products Section

APPENDIX H.8

COST COMPARISONS OF TIME-SHARED AND REMOTE-JOB-ENTRY BATCH COMPUTING

Among computer experts, especially those associated with higher education, there is a standing controversy concerning the relative merits and costs of time-shared computing and batch processing. It is probably correct to say that the majority of computer specialists favor batch processing as more effective and considerably less expensive than time-sharing, and also that most of them have had very little experience in using, managing, or maintaining a time-shared computer system. This is certainly true in Minnesota higher education. The minority position, however, was sufficiently convincing that the Pierce Report[1] of 1967 recommended the adoption of time-shared computing for instructional purposes because of its greater convenience to and efficiency for the user.

Quite aside from the merits of time-sharing, it is incumbent upon us to investigate more quantitatively the costs of that mode of computing relative to batch processing through remote terminals. If it is in fact considerably more expensive, and if remote batch processing will do the job, then Minnesota cannot afford much time-shared computing in higher education. Therefore, we have carried out a cost analysis of three modes of instructional computing:

- Remote-job-entry via medium-speed terminals (2,400 bits/second)
- Remote-job-entry via low-speed terminals (100 and 300 bits/second)
- Time-shared computing on a Class Z system dedicated to time-sharing

In Appendix H.6 it has been shown that time-shared computing mixed with batch processing on a large computer is not economical in terms of computer costs; hence, that mode has not been considered further. It will be useful at this stage to recall the functional definition of time-shared computing in terms of the user (Section 3):

- User may interact through a keyboard with a program during its execution;
- Response time of five seconds or less to a request not requiring significant computation.

The analysis here is based consistently on the figures developed in Appendix H.6 and reported in Section 3 of this study: the "average" student works 11.3 problems per year on the computer, whatever the mode of computing used. The results of the analysis are displayed in Table H.8.1 in terms of total hardware cost required to serve 2,000 students in a four-year college. Note that communications costs have not been included. By judicious use of multiplexing, they can be similar in most cases for the four alternatives of Table H.8.1, though perhaps somewhat less for the single medium-speed terminal (see Section 4.5). Another factor not included in the table is operating support, including staff. Again, this will be similar for three of the four alternatives, and somewhat lower for the Class Z dedicated time-shared computer, since this kind of machine requires very little operator attention and maintenance. (Annual operating support has been estimated in Sections 4 and 5 of this report at 30% of purchase cost for batch-processing systems, and 18% (60% of 30%) for Class Z time-shared systems.)

The conclusion from Table H.8.1 is that medium-speed remote-job-entry computing is somewhat less expensive, and that the various low-speed terminal alternatives do not differ much in cost. It must be kept in mind, however, that the services provided by remote-job-entry and time-sharing are not strictly comparable, even though the costs may be. The computing power of Class Z time-sharing systems is more limited than that available from a Class D computer. This kind of time-sharing is quite adequate for the instructional computing needs of many students – most of those in lower division, for instance. The surprising similarity in costs for batch processing and time-shared computing results from this computing power difference, and from the fact that batch processing implies more input/output than time-sharing. Referring to Tables H.6.4 and H.6.5 of Appendix H.6, the important numbers are

- about 1.5 terminal hours per problem in the time-sharing mode; and
- about 5 runs per problem, and 12,000 characters input and 68,000 characters output per problem for batch processing.

What happens is that the student at a time-shared computer terminal reads in or types in his program once, then makes changes and corrections in it on-line, storing the program on the computer disk while he works off-line to identify the changes needed. In a batch processing system, on the other hand, the entire program is read in and the necessary diagnostics, lists, and other output printed for each of the five runs necessary to complete a problem. In other words, the cost of the additional input/output required for remote batch processing offsets the cost of disk storage and the extra (but cheaper and less powerful) computing required of a small time-shared system.

This analysis has been reviewed by highly respected staff members of the computer centers at the University of Minnesota and Mankato State College, who expressed their skepticism that time-shared computing could be almost as inexpensive as batch processing. They suggested that the efficient diagnostics built into compilers on their computers would reduce the number of runs per problem from five to perhaps three. While it is true that their diagnostics are much more extensive than those of most computer systems, several users have expressed general agreement with the estimate of five runs per problem. Also, there has been little experience in Minnesota with the proposed instructional uses of computers by a large fraction of the student body, most of whom will be rather inexperienced.

A similar detailed review of the analysis was made by a member of the staff of the Kiewit Computation Center at Dartmouth College, perhaps the only institution in the nation with extensive experience in the use of computers by most of the student body, and in both the time-sharing and batch processing modes. This reviewer considered both the assumptions and results of the analysis to be reasonable.

Until more experience and information are available, the authors of this study will stand by the results in Table H.8.1, with the one reservation that the cost estimates there, although they are self-consistent and consistent with the rest of the report, are of limited accuracy. Therefore, educational objectives should play a major role in deciding which mode of computing should be used. For the interactive simulations coming into use in the social sciences and engineering, time-shared computing is almost necessary. But for training students in business data processing, as in the area vocational-technical schools, both time-sharing and the low-speed remote-job-entry modes are inappropriate. In the larger institutions, both remote-job-entry and time-shared computing will surely be needed to satisfy a variety of educational demands.

Table H.8.1. Comparison of Terminal and Computer Costs for Three Kinds of Remote-Job-Entry Computing and Time-Shared Computing (Based on the needs of 2,000 four-year college students)

	Remote-Job-Entry			Time-Sharing
	Low-Speed	Low-Speed	Medium Speed	
Data Rate (bits/second)	110	300	2,400	110
Terminals				
Number Required	20	7	1	14
Unit Cost/Month	$75/mo	$175/mo	$800/mo	$75/mo
Total Cost/Month	$1,500	$1,225	$800	$1,050
Computer Capacity				
Required Peak Compile Rate	144 FORTRAN statements/min			-----
Computer Assumed	-----	Class D	-----	Class Z
Compile Rate	3,000 FORTRAN statements/min			($6,000/terminal)
Cost/Month	-----	$40,000	-----	($150/terminal)
Required/Available Ratio	144/3,000 = 4.8%			-----
Cost of Capacity Utilized	$1,920	$1,920	$1,920	$2,100
TOTAL MONTHLY COST	$3,420	$3,145	$2,720	$3,150

APPENDIX H.9

ALTERNATIVE DEPLOYMENT CONFIGURATIONS FOR COMPUTERS IN MINNESOTA HIGHER EDUCATION

Refer to Appendix H.7 for identification of the specific types and costs of components referred to in the columns labeled "Type and Comments". The quantities listed are those developed in Section 4 of the main report.

Table H.9.1. Intra-University System

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Terminals				
Crookston	Type "m" teletype equiv.	3	$ 75/mo	$ 225
Waseca	Type "m" teletype equiv.	2	75/mo	150
Morris	Type "m" teletype equiv.	10	75/mo	750
	Type "k" remote-job-entry	1	800/mo	800
Duluth	Type "l" CRT	2	100/mo	200
	Type "m" teletype equiv.	14	75/mo	1, 050
Minneapolis	Type "m" teletype equiv.	131	75/mo	9, 825
	Type "k" remote-job-entry	18	800/mo	14, 400
	Type "i" high-speed terminal	2	2500/mo	5, 000
	Type "f" satellite computer (West Bank)	1	Cost included in computer cost	
				$32, 400
Multiplexors				
Crookston	ADS 680 or equiv.	2	$ 64/mo	$ 128
Waseca				
Morris	ADS 660 or equiv.	1	200/mo	200
Minneapolis/St. Paul	ADS 680T or equiv.	2	95/mo	190
	ADS 660 or equiv.	1	200/mo	200
				$ 718
Modems				
Morris and Twin Cities	ADS 448 or equiv. (Two 2400 bps channels)	2	$ 200/mo	$ 400
Duluth and Twin Cities	Bell 201B or equiv. 2400 bps (for 3200-6600 and query terminal communication)	2	73/mo	146
Twin Cities	Unconditioned private line (ADS)	36	93/mo	3, 348
Modem costs for low-speed terminals are included in terminal and computer costs.				
				$ 3, 894
Controllers				
Twin Cities	To support 19 medium-speed terminals	19 ports	$ 170/mo per port	$ 3, 230

Table H. 9. 1. (Continued)

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Lines				
Crookston to Morris	Voice-grade leased line	158 mi.	$ 4/mi.	$ 632
Morris to Minneapolis	Voice-grade leased line Leased-line conditioning	141 mi.	4/mi. 34	564 34
Waseca to Minneapolis	Voice-grade leased line	63 mi.	4/mi.	252
Duluth to Minneapolis	Voice-grade leased line Leased line conditioning	140	4/mi. 34	560 34
Twin Cities campus	Voice-grade leased line High-speed leased lines	149 3	10 180	1,490 540
Duluth campus	Voice-grade leased lines	14	10	140
				$ 4,246
	TOTAL COMMUNICATIONS			$12,088
Computers				
Duluth	Class F	100%	$ 12,000	$ 12,000
Twin Cities	Class B Class F (West Bank) Class E (Health Sciences) Class Z (Time-Sharing) Class E (Administrative Data Processing)	36% 100% 33% 145 terminals 1	85,000 12,000 25,000 150/ mo terminal 25,000	31,000 12,000 8,000 21,750 25,000
				$109,750
Mass Storage for Administrative Data Processing (See Table H.7.3, Appendix H.7)				
Twin Cities	827 million characters			$ 5,460
Duluth	45 million characters			388
				$ 5,848
	GRAND TOTAL			$160,086

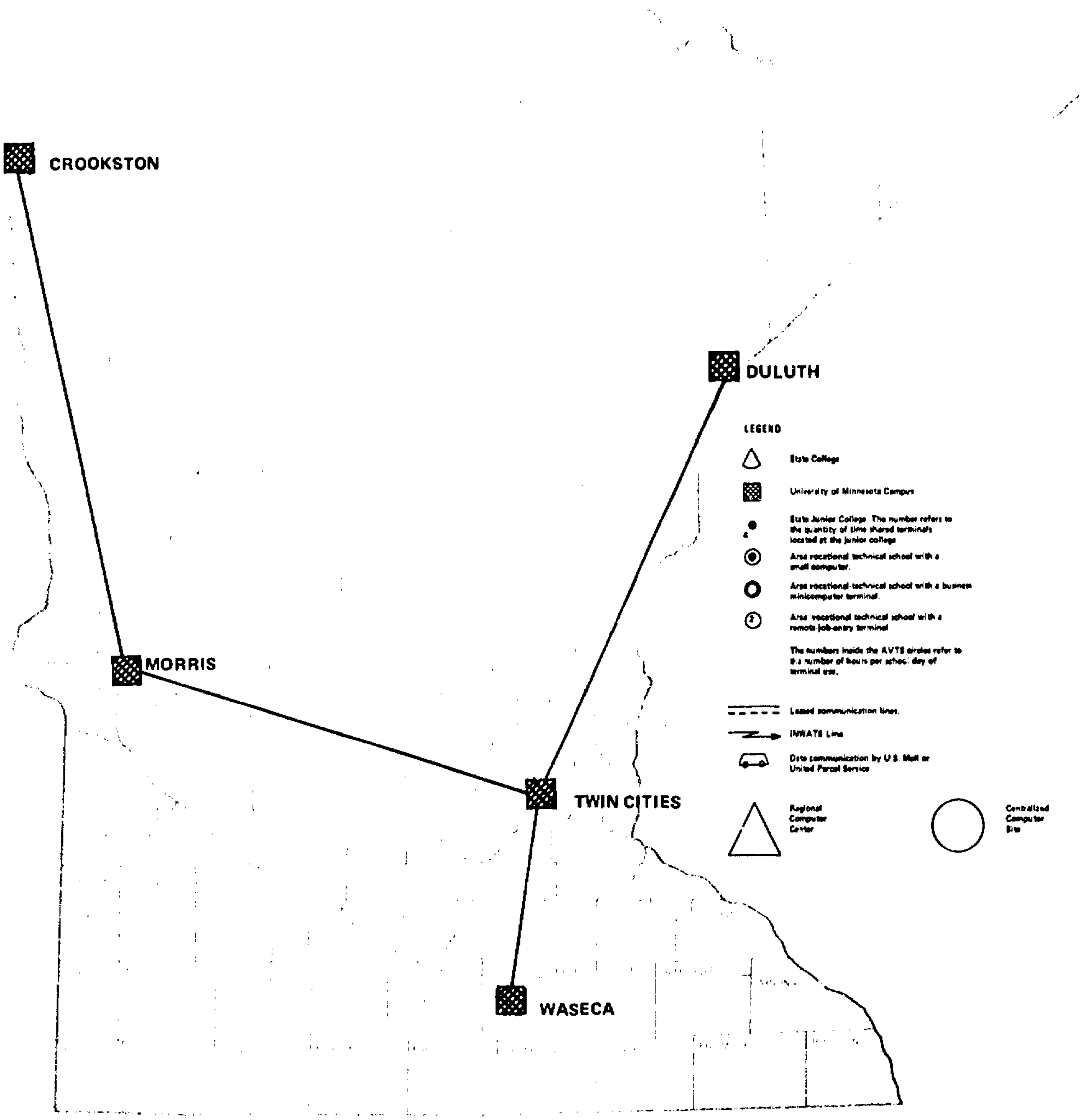

FIGURE U-1. INTRA-UNIVERSITY SYSTEM

Table H.9.2. Regionalized University System

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Terminals				
Crookston	Type "m" teletype equiv.	3	$ 75/mo	$ 225
Waseca	Type "m" teletype equiv.	2	75/mo	150
Morris	Type "m" teletype equiv.	10	75/mo	750
	Type "k" remote-job entry	1	800/mo	800
Duluth	Type "l" CRT	2	100/mo	200
	Type "m" teletype equiv.	14	75/mo	1,050
Minneapolis	Type "m" teletype equiv.	131	75/mo	9,825
	Type "k" remote-job entry	18	800/mo	14,400
	Type "i" high-speed terminal	2	2500/mo	5,000
	Type "f" satellite computer (West Bank)	1	Cost included in computer cost	
				$ 32,400
Multiplexors				
Crookston, Waseca	ADS 680 or equiv.	2	$ 64/mo	$ 128
Morris	ADS 660 or equiv.	1	200/mo	200
St. Cloud	ADS 680T or equiv.	1	95/mo	95
	ADS 660 or equiv.	1	200/mo	200
Mankato	ADS 680T or equiv.	1	95/mo	95
				$ 718
Modems				
Morris – St. Cloud	ADS 448 or equiv. (two 2400 bps channels)	2	$ 200/mo	$ 400
Duluth and Twin Cities	Bell 201B or equiv. 2400 bps (for 3200-6600 and query terminal communication)	2	73/mo	146
Twin Cities	Unconditioned private line (ADS)	36	93/mo	3,348
Modem costs for low-speed terminals are included in terminal and computer costs.				$ 3,894

Table H. 9. 2. (Continued)

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Controllers				
Twin Cities	To support 18 medium-speed terminals	18 ports	$170/port	$ 3,060
St. Cloud	To support 1 medium-speed terminal from Morris	1 port	$170/port	170
				$ 3,230
Lines				
Crookston to St. Cloud	Voice-grade leased line	195 mi.	$ 4/mi.	$ 780
Morris to St. Cloud	Voice-grade leased line	86 mi.	4/mi.	344
Waseca to Mankato	Voice-grade leased line	25 mi.	4/mi.	100
Duluth to Twin Cities	Voice-grade leased line Leased line conditioning	140 mi.	4/mi.	560 34
Twin Cities campus	Voice-grade leased lines High-speed leased lines	149 3	10 180	1,490 540
Duluth campus	Voice-grade leased lines	14	10	140
				$ 3,988
	TOTAL COMMUNICATIONS			$ 11,830
Computers				
St. Cloud (Crookston, Morris)	Class D	12%*	$ 40,000	$ 4,800
Mankato (Waseca)	Class D	2%*	40,000	800
Duluth	Class F	100%	12,000	12,000
Twin Cities	Class B Class F (West Bank) Class E (Health Sciences) Class Z (Time-Sharing) Class E (Administrative Data Processing)	35% 100% 33% 145 terminals 1	85,000 12,000 25,000 150/ terminal 25,000	30,000 12,000 8,000 21,750 25,000
				$114,350
Mass Storage for Administrative Data Processing (See Table H. 7. 3)				
Twin Cities	827 million characters			$ 5,460
Duluth	45 million characters			388
				$ 5,848
		GRAND TOTAL		$164,428

*The costs of computing services from facilities outside the system are based on average use rather than peak demand.

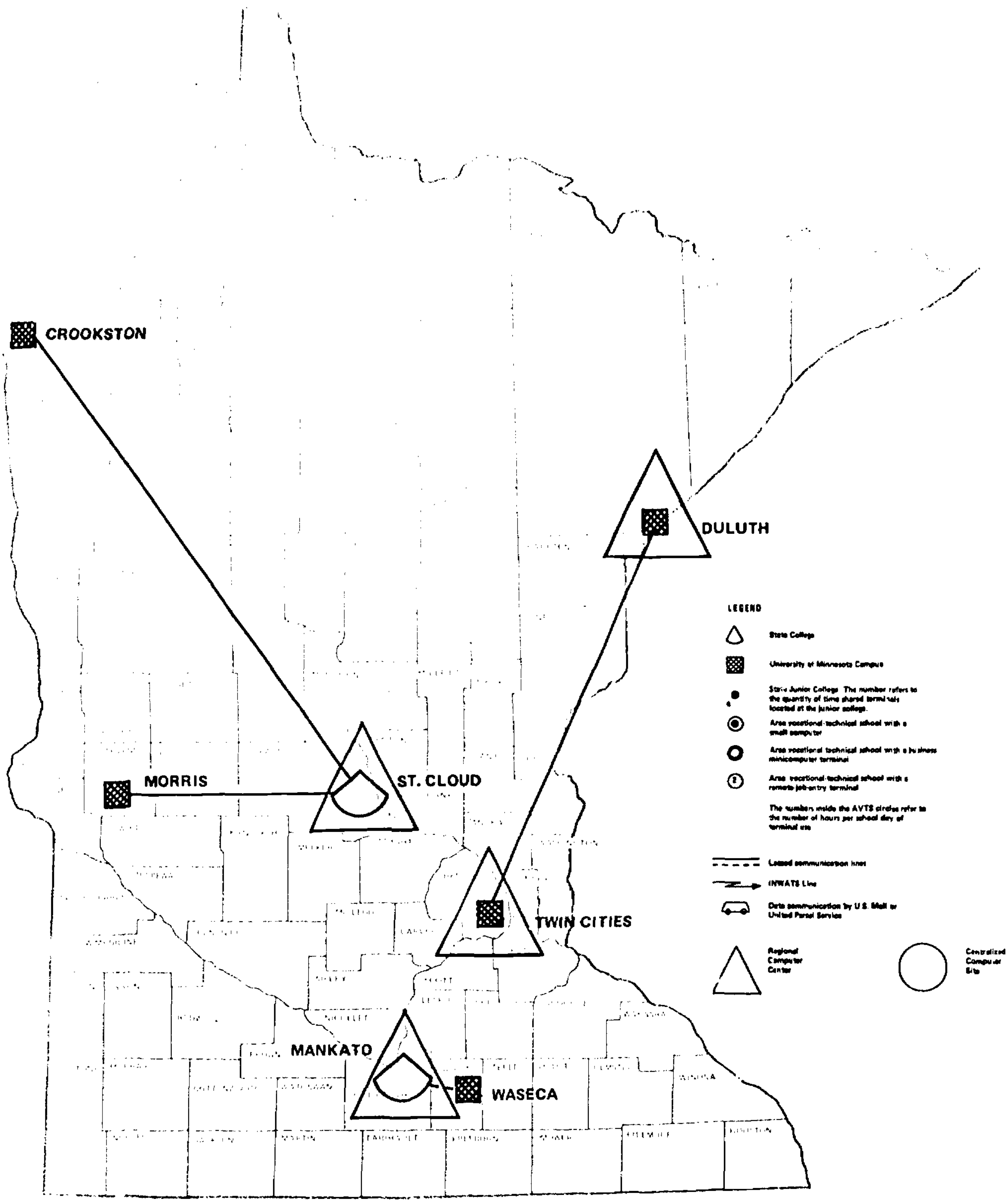

FIGURE U-2. REGIONALIZED UNIVERSITY SYSTEM

Table H.9.3. State College System with Two Hubs and INWATS Lines

	Type and Comments	Q[illegible]	Unit Cost	Monthly Cost
Terminals				
One for each of 12 terminal sites	Type "k" remote-job entry		$800/mo	$ 9,600
Note: State College Board access to Hub computers is assumed to [illegible] ate OUTWATS or excess capacity of the Hub INWATS. No cost [illegible] med for State College Board access.				
Modems				
Two for each terminal (one at terminal, one at computer)	Rixon PM-24A or equiv. 2400 bps	24	90/mo	$ 2,160
Controllers				
St. Cloud	To service 7 medium speed terminals at the three northern colleges	7 ports	$170/port	$ 1,190
Mankato	To service 5 medium speed terminals at the three southern colleges	5 ports	170/port	850
				$ 2,040
Lines				
St. Cloud, Mankato	INWATS	7	$590/mo	$ 4,130
Local Terminals to computing centers or to modems	Voice-grade leased lines (local)	5	10/mo	50
				$ 4,180
	TOTAL COMMUNICATIONS			$ 8,380
Computers				
Mankato	Class E or 60% of Class D	1	$25,000	$25,000
Moorhead	Class I	1	2,500	2,500
Bemidji	Class I	1	2,500	2,500
St. Cloud	Class E or 60% of Class D	1	25,000	25,000
Southwest	Class I	1	2,500	2,500
Winona	Class I	1	2,500	2,500
				$60,000
Mass Storage for Administrative Data Processing (See Table H.7.3)				
	426 million characters, distributed among the six colleges			$ 9,114
		GRAND TOTAL		$87,094

Table H. 9. 3. (Continued)

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Terminals				
One at each of the 12 terminal sites	Type "k" remote job entry	12	$800/mo	$ 9,600
Modems				
Moorhead	Bell 201B	1	73/mo	73
	ADS 448 (4800 bps over two 2400 bps channels)	1	200/mo	200
Bemidji	ADS 448	1	200/mo	200
	PM-24A	2*	90/mo	180
St. Cloud	ADS 448	2	200/mo	400
	Bell 201B	1	73/mo	73
	ADS (for unconditional line)	4	93/mo	372
Winona	Bell 201B	1	73/mo	73
Southwest	Bell 201B	1	73/mo	73
Mankato	Bell 201B	2	73/mo	146
	ADS (for unconditional line)	6	93/mo	558
				$ 2,348
Controllers				
St. Cloud	To service 7 medium-speed terminals at the three northern colleges	7 ports	$170/port	$ 1,190
Mankato	To service 5 medium-speed terminals at the three southern colleges	5 ports	170/port	850
				$ 2,040
Lines				
Moorhead to St. Cloud	Voice-grade leased line	2 at 154 mi	$ 4/mi	$ 1,232
Bemidji to St. Cloud	Voice-grade leased line	140 mi	$ 4/mi	560
Southwest to Mankato	Voice-grade leased line	92 mi	$ 4/mi	368
Winona to Mankato	Voice-grade leased line	118 mi	$ 4/mi	472
Local terminals to center or to modems	Voice-grade leased line	5 lines	$10/mo	50
State College Board	Assumed to use state OUT-WATS or "long Distance."		No expense allocated here.	

...required for each terminal not in immediate vicinity of the 4800 bps Modem. If two ...inals located in the vicinity of their modem or computer, subtract two from this ...requirement.

Table H. 9. 3. (Continued)

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Lines (continued)		5 lines	$34/mo	$ 170
C2 conditioning				$ 2, 852
	TOTAL COMMUNICATIONS			$ 7, 240
Computers				
St. Cloud	Class E or 60% of Class D	1	$25, 000	$25, 000
Bemidji	Class I	1	2, 500	2, 500
Moorhead	Class I	1	2, 500	2, 500
Mankato	Class E or 60% of Class D	1	25, 000	25, 000
Southwest	Class I	1	2, 500	2, 500
Winona	Class I	1	2, 500	2, 500
				$60, 000
Mass Storage for Administrative Data Processing (See Table H. 7. 3)				
	426 million characters, distributed among the six colleges			$ 9, 114
		GRAND TOTAL		$85, 954

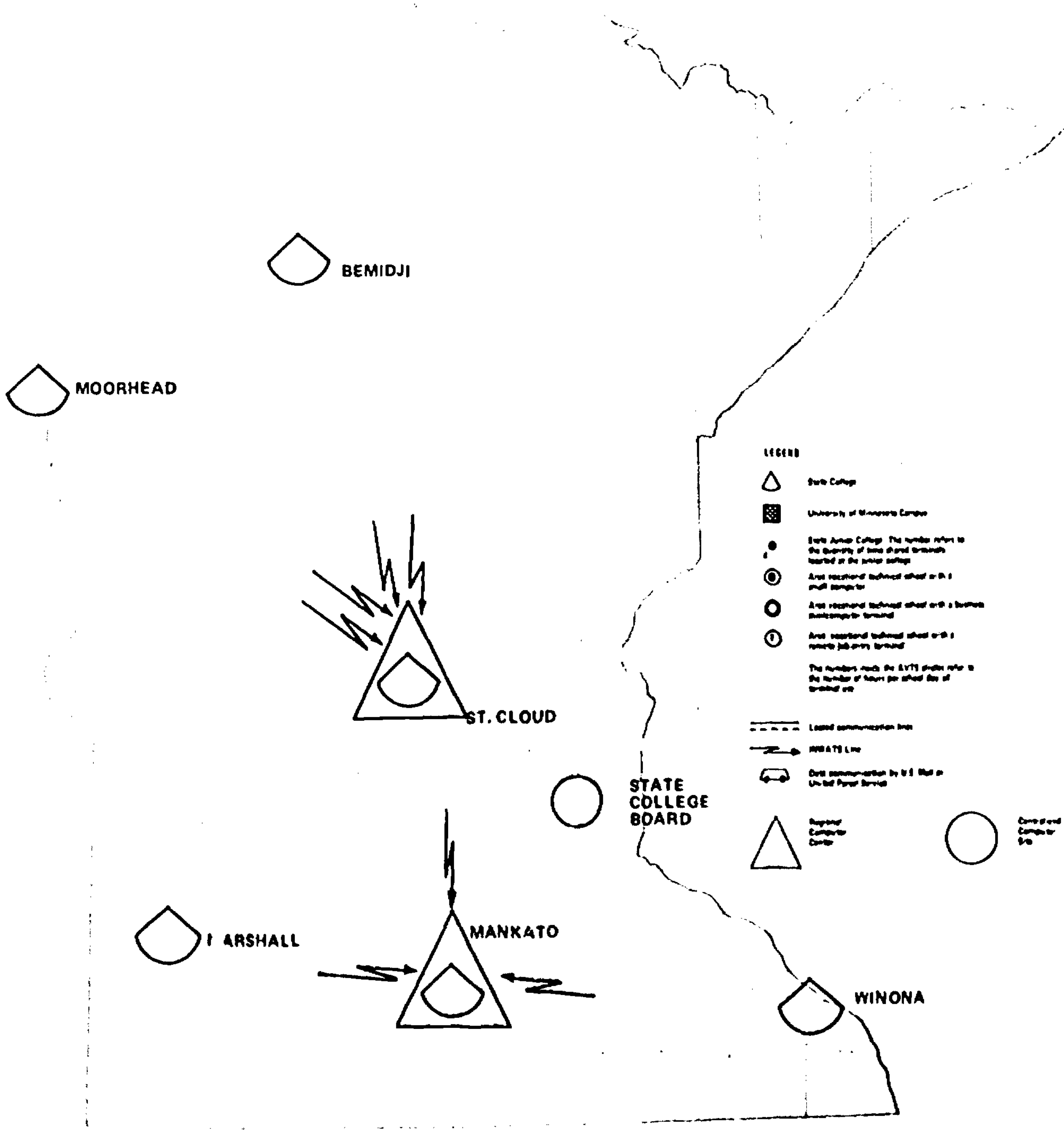

FIGURE S-1. STATE COLLEGE SYSTEM WITH TWO HUBS, INWATS COMMUNICATION

Table H.9.4 State College System with Two Hubs and Leased Lines

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Terminals				
One at each of the 16 terminal sites	Type "k" remote-job entry	16	$800/mo	$12,800
Modems				
Moorhead	ADS 448 (4800 bps in 2 2400 bps channels)	1	$200/mo	$ 200
	Bell 201B	1	73/mo	73
St. Cloud	ADS 448	3	200/mo	600
	PM-24A	6*	90/mo	540
Bemidji	ADS 448	1	200/mo	200
	PM-24A	2*	90/mo	180
Southwest	Bell 201B	1	73/mo	73
Winona	Bell 201B	1	73/mo	73
Mankato	ADS 448	5	200/mo	1,000
	Bell 201B	3	73/mo	219
	ADS (For unconditioned line)	6	93/mo	558
				$ 3,716
Controllers				
Mankato	To service 13 medium speed terminals from 5 colleges, plus 3 at Mankato	16 ports	$170/port	$ 2,720
Lines				
Moorhead to Mankato	Voice-grade	2 at 235 mi	$4/mi	$ 1,880
Bemidji to Mankato	Voice-grade	235 mi.	$4/mi	940
Southwest to Mankato	Voice-grade	92 mi	$4/mi	368
Winona to Mankato	Voice-grade	118 mi	$4/mi	472
St. Cloud to Mankato	Voice-grade	3 at 100 mi	$4/mi	1,200
State College Board assumed to use state OUTWATS lines or "long Distance."			No expense	
C2 Conditioning		7 lines	$34/mo	238
Local terminals to center or to modems		3 lines	10/mo	30
				$ 5,128

* Two of these are required for each terminal not in the vicinity of the 4800 bps modem, or the central computer. If two terminals are both in the vicinity of their modem or computer, subtract two from this requirement.

Table H. 9. 4. (Continued)

	Type and Comments	Quantity	Unit Cost	Monthly Cost
		TOTAL COMMUNICATIONS		$11, 561
<u>Computers</u>				
Mankato	Class D	1	$48, 000	$48, 000
St. Cloud	Class I	1	2, 500	2, 500
Moorhead	Class I	1	2, 500	2, 500
Bemidji	Class I	1	2, 500	2, 500
Southwest	Class I	1	2, 500	2, 500
Winona	Class I	1	2, 500	2, 500
				$60, 500
<u>Mass Storage for Administrative Data Processing</u> (See Table H. 7. 3)				
	426 million characters, distributed among the six colleges			$ 9, 114
		GRAND TOTAL		$93, 978

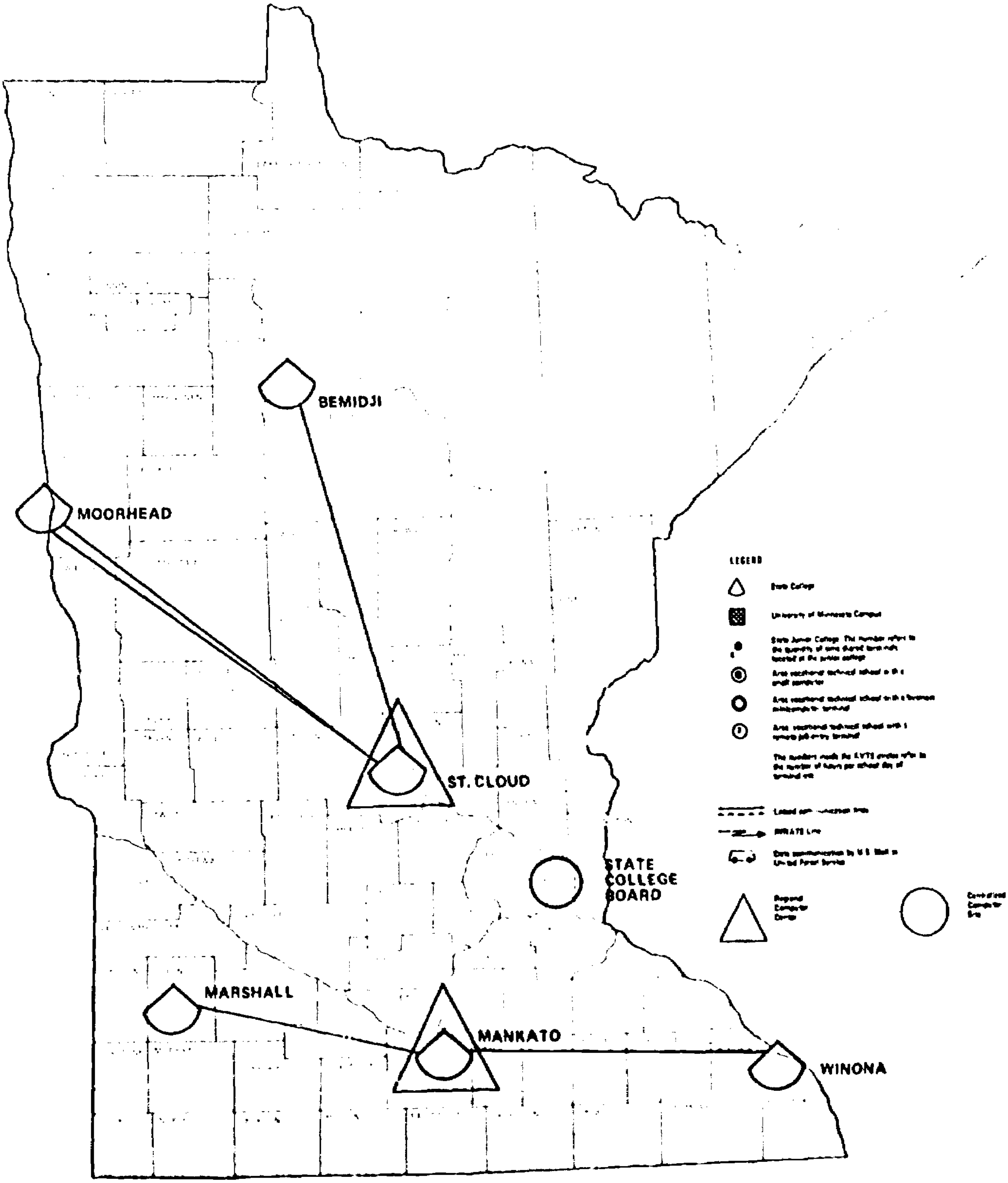

FIGURE S-2. STATE COLLEGE SYSTEM WITH TWO HUBS, LEASED LINES

Table H. 9. 5 State College System with one Hub at Mankato

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Terminals				
	Type "k" remote-job entry	16	$800/mo	$12,800
Modems				
Moorhead	ADS 448 (Dual channel)	1	$200/mo	$ 200
	Bell 201B	1	73/mo	73
Bemidji	PM-24A	2	90/mo	180
	ADS 448	1	200/mo	200
Southwest	Bell 201B	1	73/mo	73
Winona	Bell 201B	1	73/mo	73
Mankato	PM-24A	4	90/mo	360
	ADS 448	3	200/mo	600
	Bell 201B	1	73/mo	73
St. Cloud	ADS 448	5	200/mo	1,000
	Bell 201B	4	73/mo	292
	ADS (for unconditioned line)	4	93/mo	372
				$ 3,496
Controllers				
St. Cloud	To service 16 medium speed terminals	16 ports	$170/port	$ 2,720
Lines				
Southwest to St. Cloud	Voice grade	112 mi	$4/mi	$ 448
Winona to St. Cloud	Voice grade	162 mi	$4/mi	648
Mankato to St. Cloud	Voice grade	4 at 100 mi	$4/mi	1,600
Moorhead to St. Cloud	Voice grade	2 at 154 mi	$4/mi	1,232
Bemidji to St. Cloud	Voice grade	140 mi	$4/mi	560
C2 Conditioning		8	34/mo	272
Local terminals to modems or computer		2	$10/mo	20
				$ 4,780
			TOTAL COMMUNICATIONS	$10,996

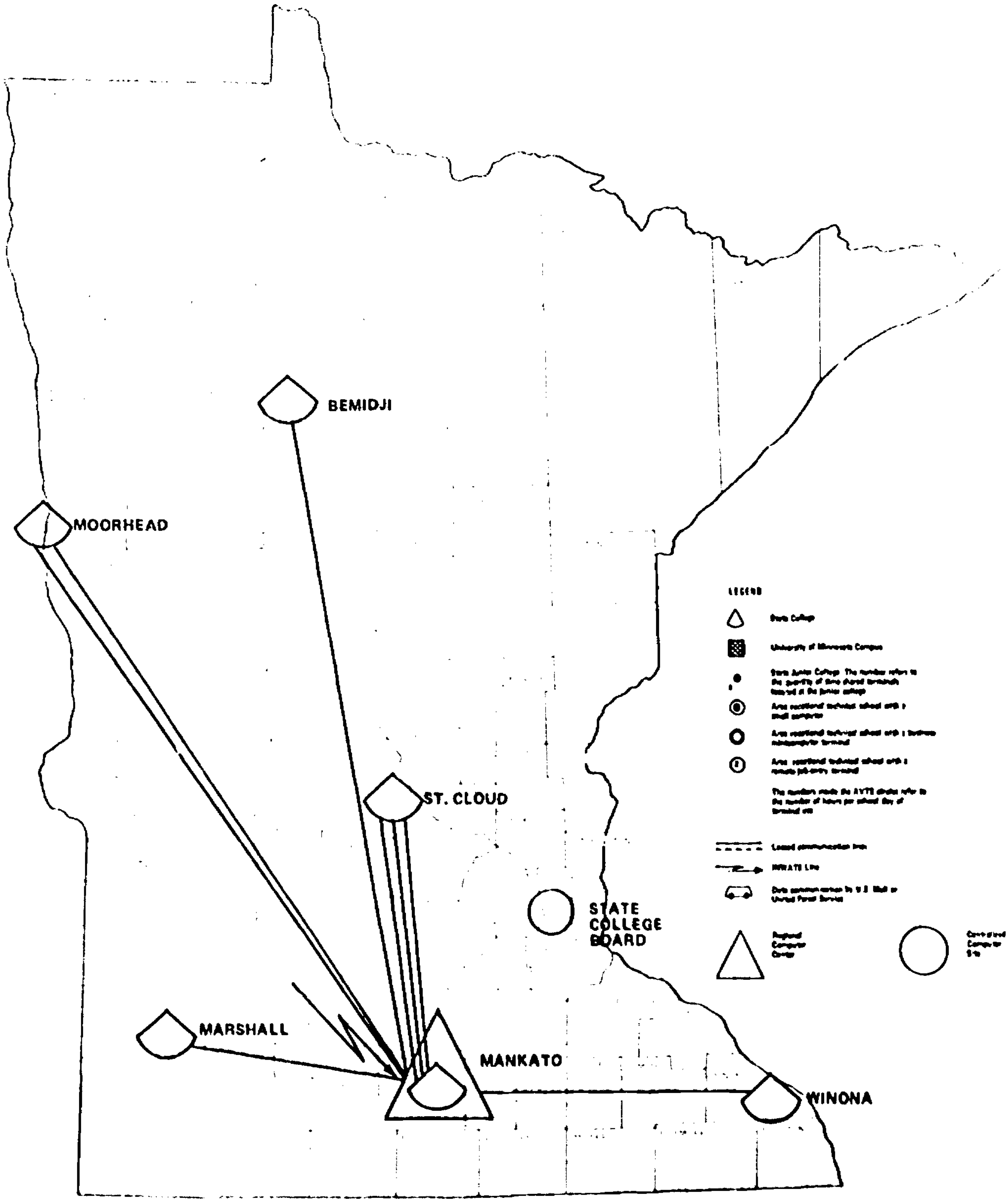

FIGURE S-3. STATE COLLEGE SYSTEM WITH ONE HUB AT MANKATO

Table H. 9. 6. State Colleges with Hub at St. Cloud

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Computers				
St. Cloud	Class D	1	$43, 000	$48, 000
Mankato	Class I	1	2, 500	2, 500
Moorhead	Class I	1	2, 500	2, 500
Bemidji	Class I	1	2, 500	2, 500
Southwest	Class I	1	2, 500	2, 500
Winona	Class I	1	2, 500	2, 500
				$60, 500
Mass Storage for Administrative Data Processing (See Table H. 7. 3)				
	426 million characters distributed among the six colleges			$ 9, 114
			GRAND TOTAL	$93, 440

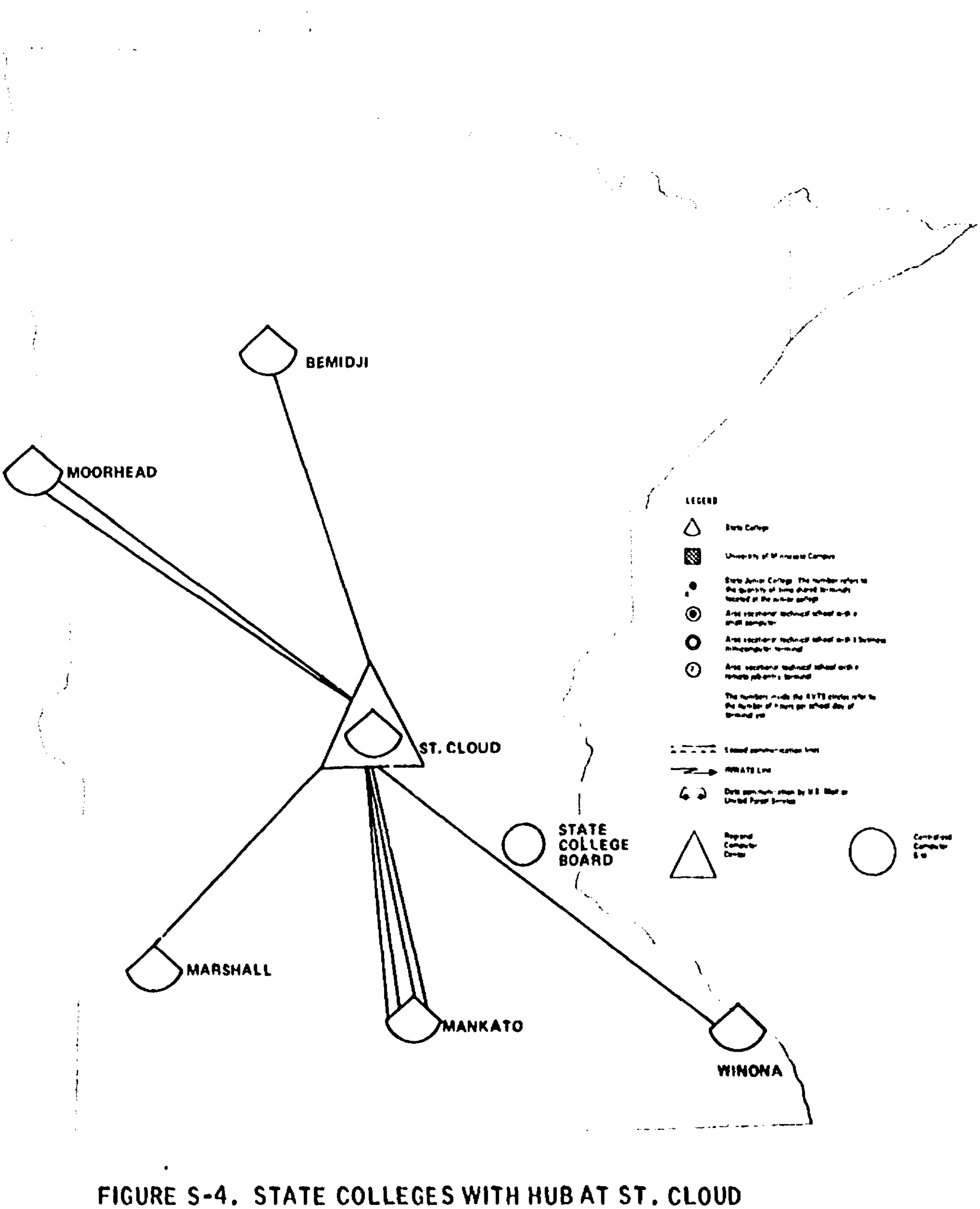

FIGURE S-4. STATE COLLEGES WITH HUB AT ST. CLOUD

Table H.9.7. Central Administrative System for Junior Colleges

	Type and Comments	Quantity	Unit Cost	Monthly Cost
	Cards are shipped to central computer center by mail or United Parcel Service. Listings from computer run are returned the same way.			
Computer	Class F	1		$10,000
Mass Storage for Administrative Data Processing (See Table H.7.3)				
	204 million characters			$ 1,333
			GRAND TOTAL	$11,333

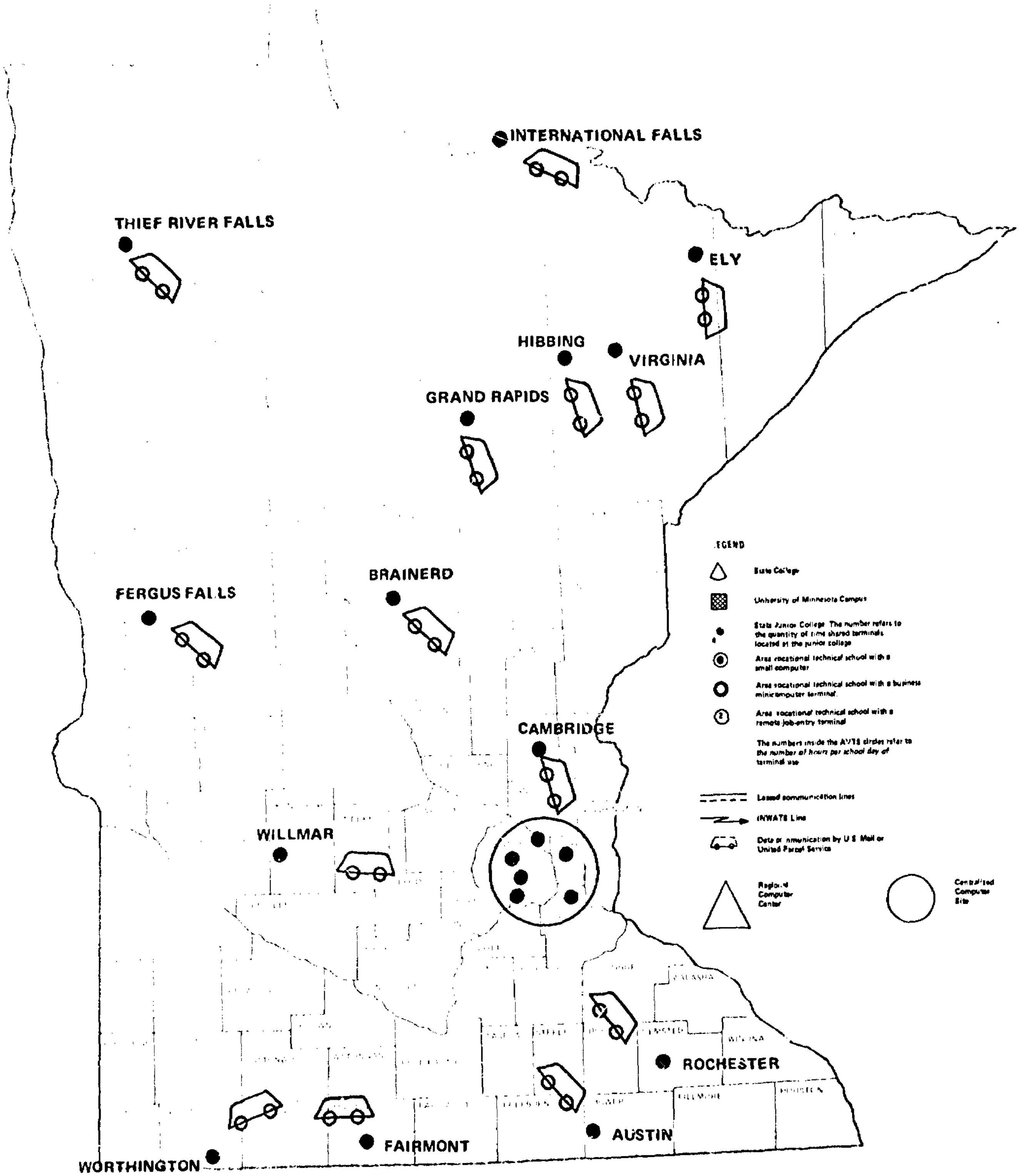

FIGURE JA-1. CENTRAL ADMINISTRATIVE SYSTEM FOR JUNIOR COLLEGES

Table H.9.8. Central Time-Sharing System for Junior Colleges

	Type and Comments	Quantity	Unit Cost	Monthly Cost
<u>Terminals</u>				
Colleges outside Twin Cities area	Type "m", including modem	36	$75/mo	$ 2,700
Colleges in Twin Cities	Type "m", including modem	46	75/mo	3,450
				$ 6,150
<u>Multiplexors</u>				
Ely	ADS 680 Multiplexor for multidrop line configuration. Up to four low-speed terminals per location.	1	$64/mo	$ 64
Virginia		1	64/mo	64
Hibbing		1	64/mo	64
Grand Rapids		1	64/mo	64
Brainerd		1	64/mo	64
Cambridge		1	64/mo	64
Fergus Falls		1	64/mo	64
Willmar		1	64/mo	64
Worthington		1	64/mo	64
Fairmont		1	64/mo	64
Austin		1	64/mo	64
Rochester		3	64/mo	192
Twin Cities	ADS 680T for termination of 16 channels	3	95/mo	285
				$ 1,181
<u>Lines</u>				
International Falls to Ely	Voice-grade leased lines	87 mi	$4/mi	$ 348
Ely to Virginia	Voice-grade leased lines	41 mi	$4/mi	164
Virginia to Hibbing	Voice-grade leased lines	16 mi	$4/mi	64
Hibbing to Grand Rapids	Voice-grade leased lines	35 mi	$4/mi	140
Grand Rapids to Brainerd	Voice-grade leased lines	70 mi	$4/mi	280
Brainerd to Cambridge	Voice-grade leased lines	73 mi	$4/mi	292
Cambridge to Twin Cities	Voice-grade leased lines	40 mi	$4/mi	160
Thief River Falls to Fergus Falls	Voice-grade leased lines	129 mi	$4/mi	516
Fergus Falls to Willmar	Voice-grade leased lines	97 mi	$4/mi	388
Willmar to Twin Cities	Voice-grade leased lines	88 mi	$4/mi	352
Worthington to Fairmont	Voice-grade leased lines	58 mi	$4/mi	232

Table H. 9. 8 (Continued)

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Lines (continued				
Fairmont to Austin	Voice-grade leased lines	75 mi	$4/mi	$ 300
Austin to Rochester	Voice-grade leased lines	36 mi	$4/mi	144
Rochester to Twin Cities	Voice-grade leased lines	72 mi	$4/mi	288
				$ 3,668
	TOTAL COMMUNICATIONS			$ 4,849
Computer	Class Z time-shared system	82 ports	$150/ port	$12,300
			GRAND TOTAL	$23,299

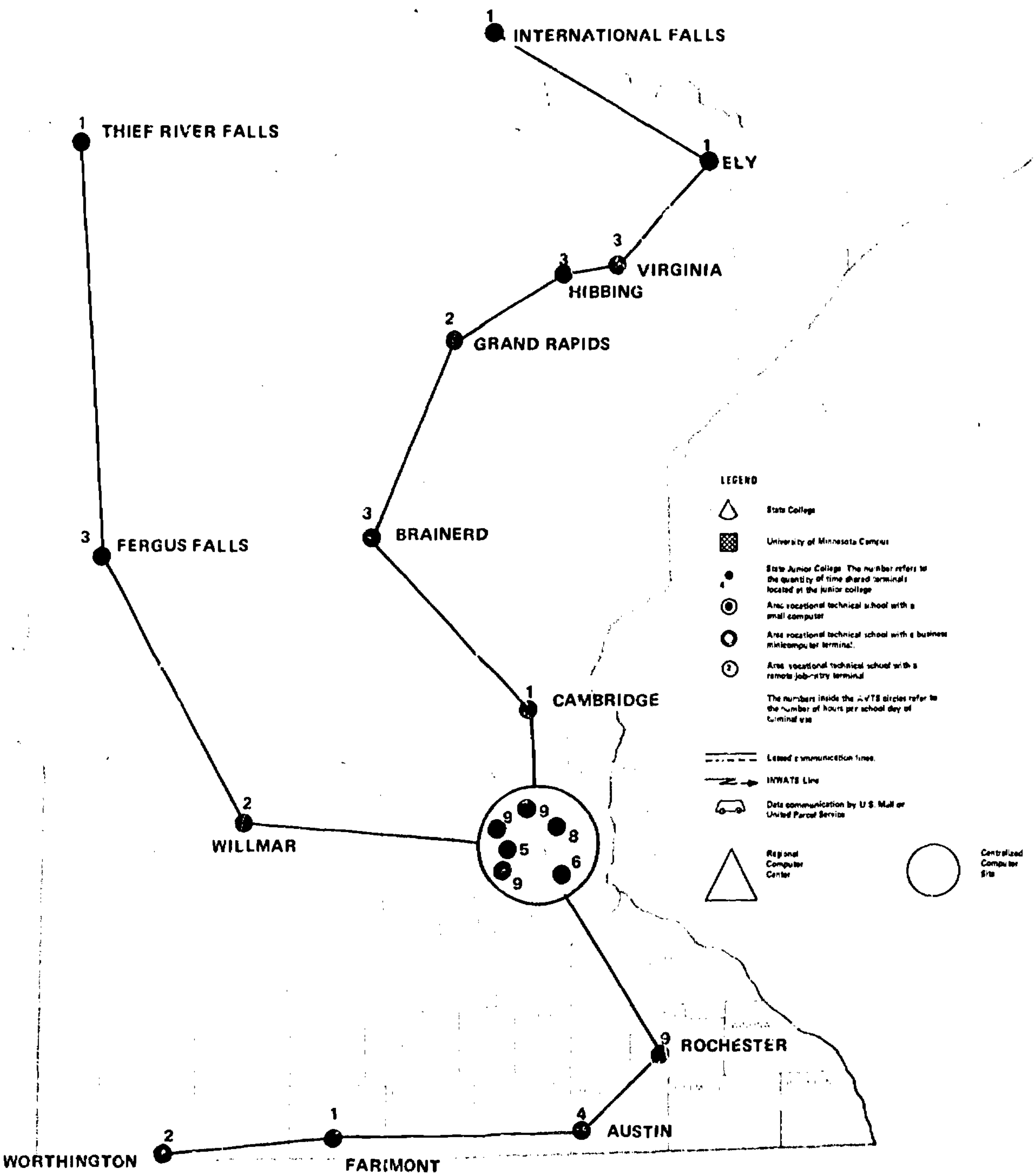

FIGURE JI-1. CENTRAL TIME-SHARING FOR JUNIOR COLLEGES

Table H.9.9. Junior College Time-Sharing System Using Regional Computer Centers

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Terminals				
Colleges Outside Twin Cities Area	Type "m" including modem	36	$75/mo	$ 2,700
Colleges In Twin Cities Area	Type "m" including modem	46	75/mo	3,450
				$ 6,150
Multiplexors				
Ely	ADS 680 Multiplexor for multidrop line configuration. Up to four low-speed terminals per location.	1		
Virginia		1		
Hibbing		1		
Grand Rapids		1		
Brainerd		1		
Fergus Falls		1	$64/mo	$ 832
Willmar		1		
Worthington		1		
Fairmont		1		
Rochester		3		
Austin		1		
St. Cloud	ADS 680T Terminator	2	95/mo	190
Mankato	ADS 680T Terminator	2	95/mo	190
				$ 1,212
Lines				
International Falls to Ely	Voice-grade leased line	87 mi	$4/mi	$ 348
Ely to Virginia	Voice-grade leased line	41 mi	$4/mi	164
Virginia to Hibbing	Voice-grade leased line	35 mi	$4/mi	140
Hibbing to Grand Rapids	Voice-grade leased line	70 mi	$4/mi	280
Grand Rapids to Brainerd	Voice-grade leased line	73 mi	$4/mi	292
Brainerd to St. Cloud	Voice-grade leased line	55 mi	$4/mi	220
Thief River Falls to Fergus Falls	Voice-grade leased line	129 mi	$4/mi	516
Fergus Falls to Willmar	Voice-grade leased line	97 mi	$4/mi	388
Willmar to St. Cloud	Voice-grade leased line	50 mi	$4/mi	200
Cambridge to Twin Cities	Voice grade leased line	40 mi	$4/mi	160
Worthington to Fairmont	Voice-grade leased line	58 mi	$4/mi	232

Table H. 9. 9. (Continued)

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Lines (continued)				
Fairmont to Mankato	Voice-grade leased line	40 mi	$4/mi	$ 160
Rochester to Austin	Voice-grade leased line	36 mi	$4/mi	144
Austin to Mankato	Voice-grade leased line	60 mi	$4/mi	240
				$ 3,484
	TOTAL COMMUNICATIONS			$ 4,696
Computers				
Mankato - 16 Terminals	Class D	7.5%*	40,000	$ 3,000
St. Cloud - 19 Terminals	Class D	9%*	40,000	3,600
Twin Cities - 47 Terminals	Class Z time-shared system	47 ports	$150/port	7,050
				$13,650
			GRAND TOTAL	$24,496

* The costs of computing service from facilities outside the system are based on expected average use rather than on peak demand.

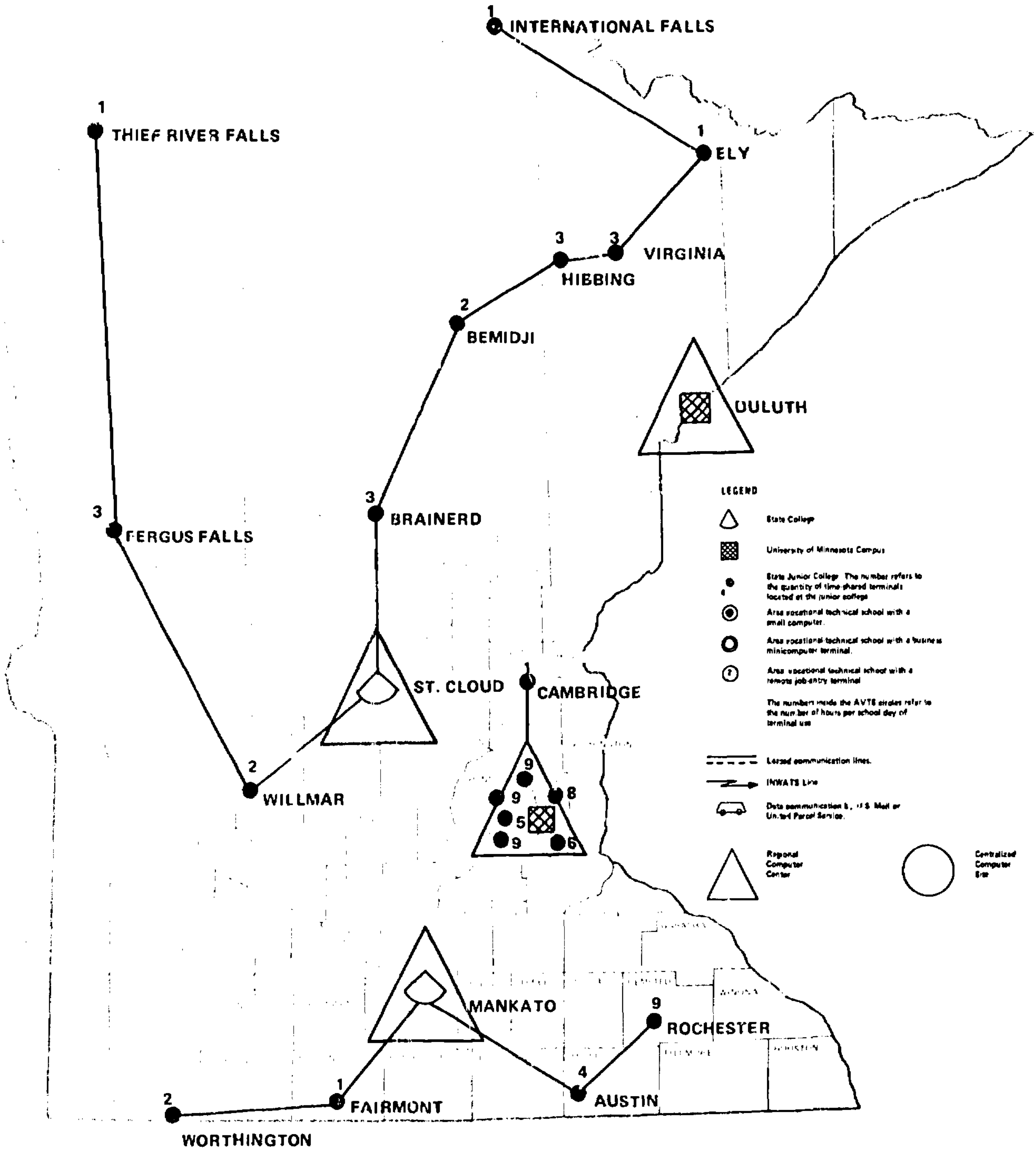

FIGURE JI-2. JUNIOR COLLEGE TIME-SHARING USING REGIONAL CENTERS

Table H.9.10. Area Vocational-Technical Schools Using Centralized Computer

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Terminals				
	Type "k" remote-job entry terminals (without stand-alone capability)	7	$ 800/mo	$ 5,600
	Type "i" business mini-computer terminals	17	2500/mo	42,500
				$48,100
Modems				
One at each remote location outside Twin Cities area.	Rixon PM-24A 2400 bps Dial-up or equiv.	20	$ 90/mo	$ 1,800
One for each INWATS line	Rixon PM-24A 2400 bps Dial-up or equiv.	13	90/mo	1,170
Two for each local school	Bell 201B 2400 bps and conditioning	4	107/mo	428
				$11,168
Lines				
	100 hours of central computer time are needed per 8-hour day by the schools not within the no-charge calling area of the center (those requiring 12 hours are assumed to work on a second shift, rather than having an additional terminal).			
	Thirteen INWATS lines would be required to supply the 100 hours per day needed.			
Outside Twin Cities area	INWATS	13	$590/mo	$ 7,670
Within Twin Cities area	Voice-grade leased lines	25 mi	$4/mi	100
				$ 7,770
	TOTAL COMMUNICATIONS			$18,938
Computer				
The 24 terminals require the equivalent of 17 8- or 12-hour shifts per school day. Each shift is equivalent to one-half of a Class H computer, or 850 transactions/min. during an 8- to 12-hour prime shift.	Class F (800 transactions/min)	106%	$12,000	$12,800
			GRAND TOTAL	$79,838

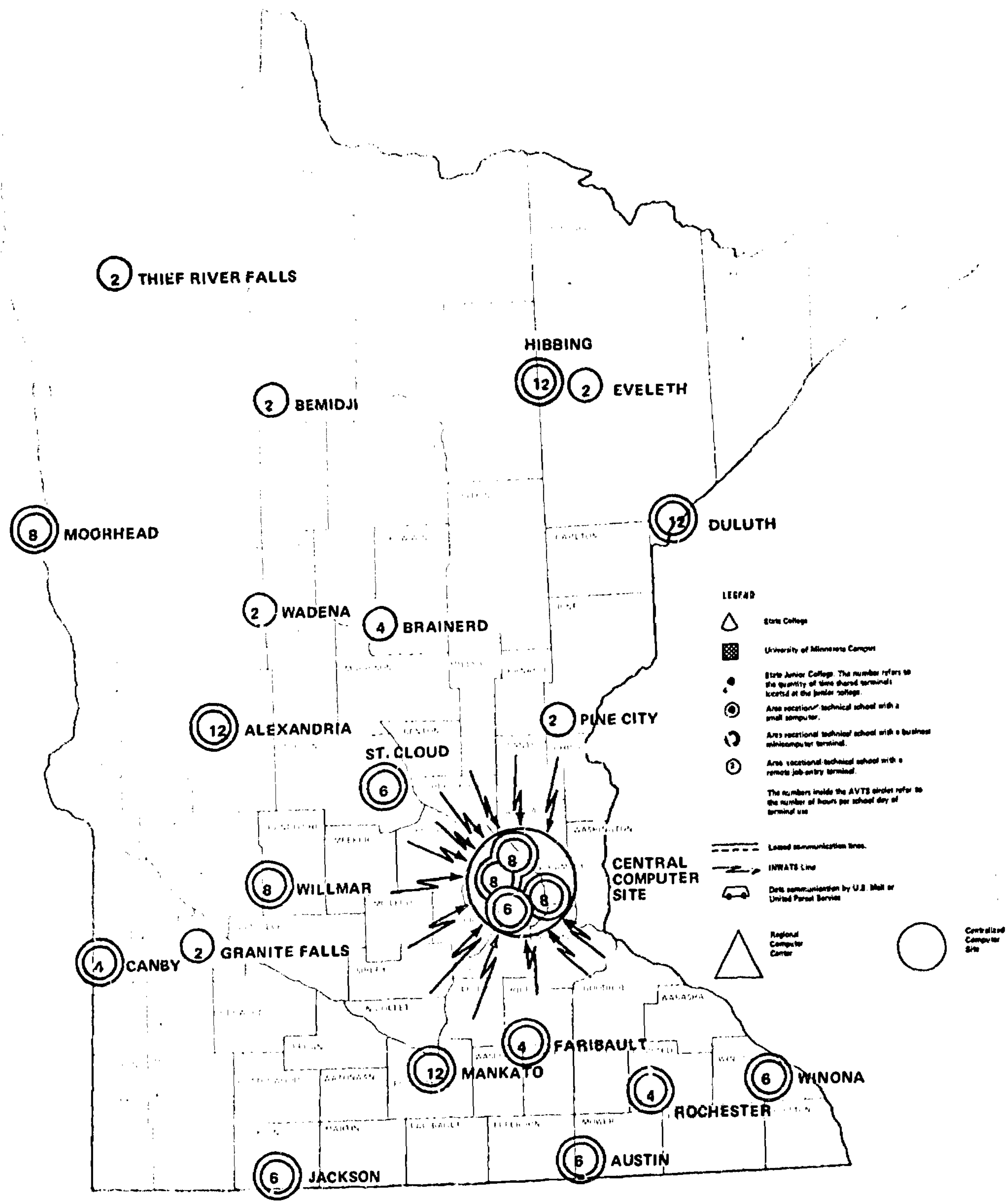

FIGURE V-1. AREA VOCATIONAL/TECHNICAL SCHOOLS USING CENTRAL COMPUTER

Table H.9.11. Area Vocational-Technical Schools Using Regional Centers

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Terminals				
	Type "k" remote-job entry terminals	7	$ 800/mo	$ 5,600
	Type "i" business mini-computer terminals (non-center)	10	2500/mo	25,000
	Type "i" terminals at: Duluth, Mankato, Mpls./St. Paul, St. Cloud (center)	7	2500/mo	17,500
				$48,100
Modems				
Users without private lines (INWATS users)	2400 bps dial-up Rixon PM-24A or equiv.	10	$ 90/mo	$ 900
	2400 bps dial-up Rixon PM-24A or equiv. (at computers)	4	90/mo	360
Users with private lines, located at a distance from centers:	2400 bps, Bell 201B (at terminals)	7	107/mo	749
Moorhead Willman Alexandria Hibbing Faribault Austin Rochester	2400 bps, Bell 201B (at computers)	7	107/mo	749
Users located near centers:	2400 bps dial-up Rixon PM-24A or equiv. (at terminals)	7	90/mo	630
Duluth Mpls./St. Paul Mankato St. Cloud	2400 bps dial-up Rixon PM-24A or equiv. (at computers)	7	90/mo	630
				$ 4,018

Table H. 9. 11. (Continued)

		Type and Comments	Quantity	Unit Cost	Monthly Cost
Lines					
		INWATS (32 hours capacity during 8-hour/day shift)	4	$590	$ 2,360
Moorhead to St. Cloud		Voice-grade leased lines	154 mi	$4/mi	616
Alexandria to St. Cloud		Voice-grade leased lines	61 mi	$4/mi	244
Willmar to St. Cloud		Voice-grade leased lines	52 mi	$4/mi	208
Faribault to Mankato		Voice-grade leased lines	38 mi	$4/mi	142
Rochester to Mankato		Voice-grade leased lines	78 mi	$4/mi	312
Austin to Mankato		Voice-grade leased lines	60 mi	$4/mi	240
Hibbing to Duluth		Voice-grade leased lines	60 mi	$4/mi	240
Local lines from schools in vicinity of centers to the center computers		Voice-grade leased lines	35 [illegible]	$4/mi	140
					$ 4,502
		TOTAL COMMUNI[illegible]S			$ 8,520
Computers	Equiv. number of terminals serviced during 8-12 hour day				
Mankato	3.75	Class D	3.4[illegible]	[illegible]0,000	$ 1,300
St. Cloud	4.75	Class D	4.[illegible]	[illegible]0,000	1,700
Twin Cities	4.75	Class B	3.[illegible]	[illegible],000	2,600
Duluth	3	Class F	18.8%	[illegible]2,000	2,300
					$ 7,900
				GRAND TOTAL	$64,520

Each equivalent terminal is assumed to work at about one-half the rate of a Class H computer (100 transactions/minute). The ratio of this to the transaction capacity of the computer to which the terminals are connected gives the per cent usage of that computer.

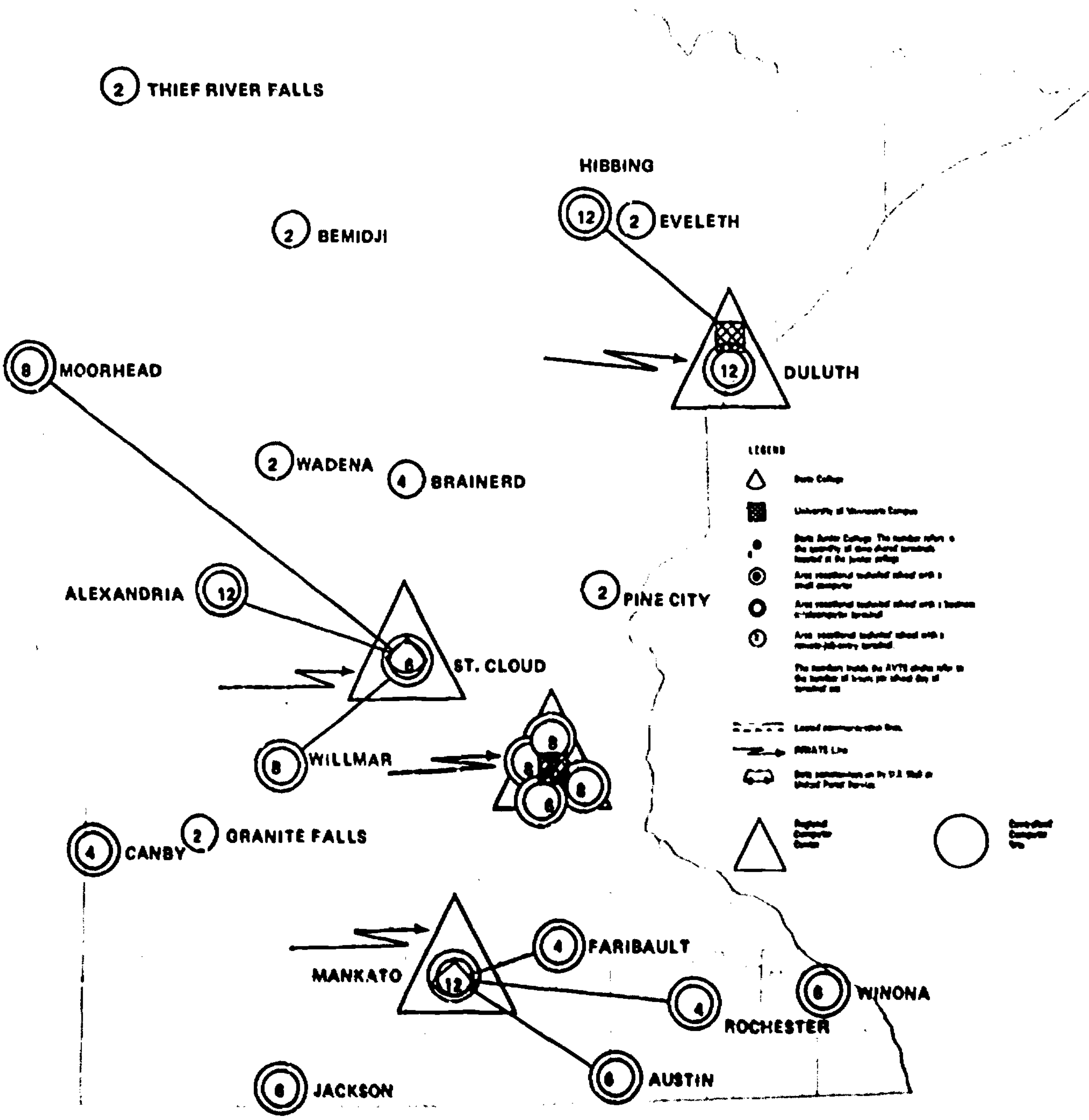

FIGURE V-2. AREA VOCATIONAL TECHNICAL SCHOOLS USING REGIONAL CENTERS

Table H.9.12. Area Vocational-Technical Schools with Small Computers and Terminals

	Type and Comments	Quantity	Unit Cost	Monthly Cost
Terminals				
	Type "k" remote-job entry terminals	7	$ 800/mo	$ 5,600
	Type "i" minicomputer terminals (noncenter locations)	8	2500/mo	20,000
	Type "i" minicomputer terminals (center locations)	7	2500/mo	17,500
				$43,100
Modems				
Users without private lines (INWATS Users)	2400 bps dial-up Rixon PM-24A or equiv. (at terminals)	10	$ 90/mo	$ 900
	2400 bps dial-up Rixon PM-24A or equiv. (at computer)	4	90/mo	360
Users located at a distance from the center:	2400 bps, Bell 201B (at terminals)	5	107/mo	535
Moorhead Willmar Faribault Austin Rochester	2400 bps, Bell 201B (at computer)	5	107/mo	535
Users located near centers:	2400 bps, dial-up Rixon P.M-24A or equiv. (at terminals)	7	90/mo	680
Duluth Mpls./St. Paul Mankato St. Cloud	2400 bps, dial-up Rixon PM-24A or equiv. (at computer)	7	90/mo	680
				$ 3,690
Lines				
	INWATS (32 hours capacity during 8 hour/day shift)	4	$590	$ 2,360
Moorhead to St. Cloud	Voice-grade leased line	154 mi	$4/mi	616
Willmar to St. Cloud	Voice-grade leased line	52 mi	$4/mi	208
Faribault to Mankato	Voice-grade leased line	38 mi	$4/mi	152

Table H. 9. 12. (Continued)

		Type and Comments	Quantity	Unit Cost	Monthly Cost
Lines (continued					
Rochester to Mankato		Voice-grade leased lines	78 mi	$4/mi	$ 31 2
Austin to Mankato		Voice-grade leased lines	60 mi	$4/mi	240
Local lines from schools in vicinity of centers to the center computers			35 mi	$4/mi	140
					$ 4,028
		TOTAL COMMUNICATIONS			$ 7, 718
Computers	Equivalent no. of terminals serviced during 8-12 hour day				
Mankato	2.75	Class D	2.5%	$40,000	$ 1,000
St. Cloud	3.75	Class D	3.4%	40,000	1,400
Twin Cities	4.75	Class B	3.0%	85,000	2,600
Duluth	2	Class F	12.5%	12,000	1,500
Hibbing	1	H (360/25)			4,000
Alexandria	1	H (360/25)			4,000
					$14,500
			GRAND TOTAL		$62,818

Each equivalent terminal is assumed to work at about one-half the rate of a Class H computer (100 transactions/minute). The ratio of this to the transaction capacity of the computer to which the terminals are connected gives the per cent usage of that computer.

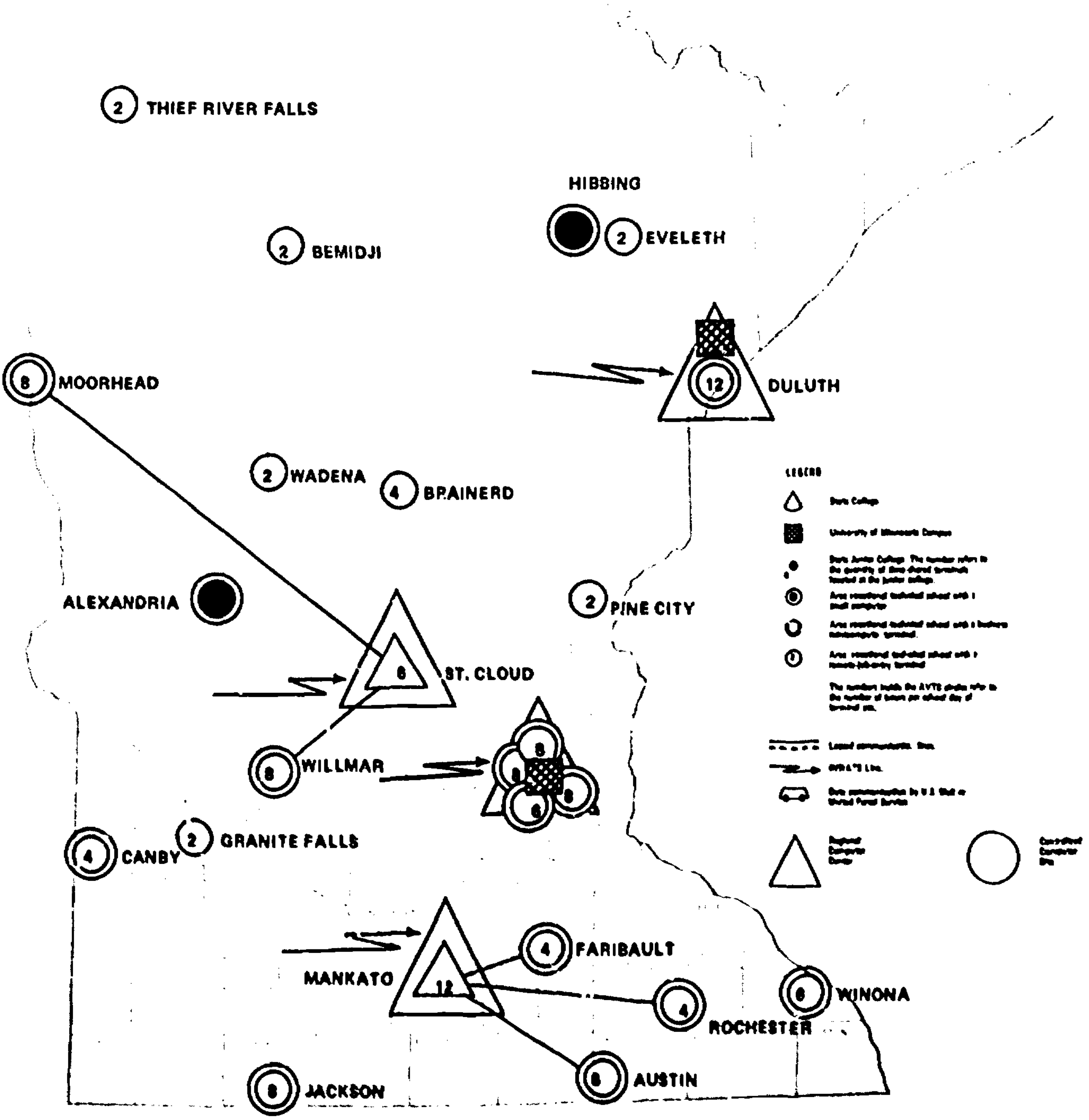

FIGURE V-3. AREA VOCATIONAL SCHOOLS USING SMALL COMPUTERS AND TERMINALS TO REGIONAL CENTERS

Table H.9.13. Deployment Configuration R-1
Fully Regionalized System

Associated Figure: R-1

This configuration is essentially the sum of the regionalized configurations U-2, S-2, JI-2, and V-2 for the four public systems of higher education in Minnesota. The only additional cost savings which can be achieved within higher education by full regionalization are as follows:

- Addition of Crookston to the string of junior colleges from Thief River Falls, rather than direct connection to St. Cloud

  Saving: $592/month

- Addition of Waseca to the string of junior colleges from Rochester and Austin, rather than direct connection to Mankato.

  Saving: $ 76/month

- Sharing of a single dual-channel leased line by the state college and AVTS in Winona.

  Saving: $252/month

In each case, the saving in line costs is partly offset by more expensive modem or multiplexor requirements.

It should also be noted that the first two savings accrue not from full regionalization, but from addition of the Waseca and Crookston Technical Colleges to the Junior College System configuration, whatever it may be.

The following table summarizes the monthly costs of this configuration.

Configuration	Computer System	Mass Storage	Terminals	Communications	Staff	Total
U-2	114,350	5,848	32,400	11,830	164,428	$328,856
S-2	60,000	9,114	9,600	7,240	85,954	171,908
JI-2	13,650	--	6,150	4,696	24,496	48,992
V-2	7,900	--	48,100	8,520	--	64,520
Savings	--	--	--	920	--	920
Totals	195,900	14,962	96,250	31,366	274,878	$613,356 per month

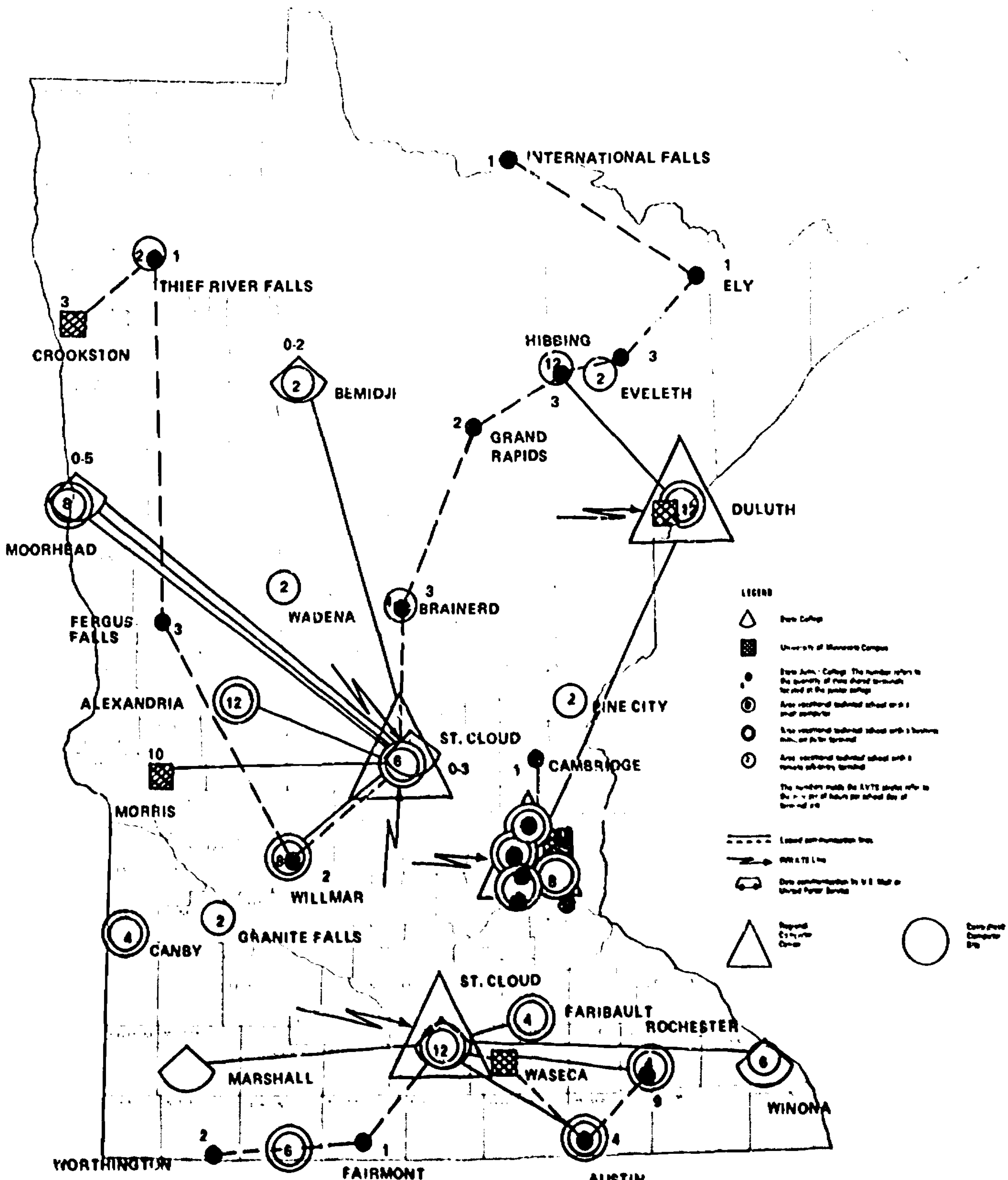

FIGURE R-1. FULLY REGIONALIZED SYSTEM

Appendix H.10

Summary of Enrollment Data And Projections for Minnesota Post-Secondary Educat
July 1970

This appendix lists the enrollment and projected enrollment data used for the analysis in the main report. Sources of data are identified in footnotes. In some cases, a set of data may not agree exactly with the total quoted for it. Where the discrepancy is small, this may result from rounding off uncertain numbers. Where the discrepancy is larger, the cause may be use of data from two or more sources; e.g., projections for individual institutions from a system administration, and overall Higher Education Coordinating Commission estimates for a system or for all systems. When data are needed for years other than those listed, they are obtained by linear interpolation.

Appendix H.10. Summary of Enrollment Data and Projections for Minnesota Post-Secondary Education

	(Actual)		(Projected)			
	1969-70 a		1975-76		1980-81	
	Total	F.T.E.	Total d	F.T.E. f	Total d	F.T.E. f
University of Minnesota System Totals	50,415	44,610	63,050[c]	56,900	74,350	66,600
Twin Cities	42,884	37,327	50,150[c]	43,700	57,050	49,700
Duluth	5,580	5,259	8,500[c]	8,050	11,000	10,400
Morris	1,510	1,575	2,800[c]	2,900	4,000	4,150
Crookston	441	459	1,000[c]	1,014	1,500	1,560
Waseca	--	--	600	600	800	800
State Colleges System Totals	37,681	35,528	48,844	46,100	61,412	58,000
Bemidji	4,716	4,652	5,857	5,790	7,286	7,180
Mankato	12,090	10,960	15,045	13,640	18,713	17,000
Moorhead	5,235	5,249	6,988	7,000	8,691	8,710
St. Cloud	9,557	8,863	12,028	11,160	14,961	13,870
Southwest	2,206	2,153	4,209	4,100	5,895	5,750
Winona	3,877	3,651	4,717	4,440	5,868	5,530
State Junior Colleges System Totals	17,544	15,914	29,080	26,200	35,450	32,200
Anoka-Ramsey	2,127	1,869	3,420	3,000	4,000	3,500
Austin	932	859	1,300	1,200	1,500	1,400
Brainerd	535	527	650	640	750	740
Cambridge	--	--	400	365	700	640
Fairmont	--	--	400	365	700	640
Fergus Falls	602	578	780	750	900	885
Hibbing	811	786	900	870	1,000	957
Inver Hills	--	--	2,000	1,800	3,000	2,700
Itasca	610	601	750	740	800	790
Lakewood	1,093	939	3,000	2,600	3,500	3,000
Mesabi	783	778	900	900	1,000	990
Metropolitan	1,154	935	2,000	1,600	3,000	2,400
Normandale	2,531	2,167	3,500	3,000	4,000	3,400
North Hennepin	1,753	1,592	3,300	3,000	4,000	3,600
Northland	379	352	435	400	500	465
Rainy River	369	335	440	400	500	450
Rochester	2,140	1,930	3,000	2,700	3,500	3,150
Vermilion	258	243	350	330	400	375
Willmar	770	717	805	750	900	840
Worthington	697	706	750	760	800	825

Appendix H.10. Summary of Enrollment Data and Projections for Minnesota Post-Secondary Education (Continued)

	(Actual)		(Projected)			
	1969-70 a		1975-76		1980-81	
	Total	F.T.E.	Total d	F.T.E. f	Total d	F.T.E. f
Private Colleges (4-year Totals for All Minnesota Private 4-year Colleges	27,137	27,627	33,189[c]	33,800	36,427[c]	37,200
Area Vocational-Technical Schools b Totals for State	13,435		20,449[c]		39,850[c]	
	1969-70		1974-75		1979-80	
	Data Processing b	Accounting b	Data Processing b	Accounting b	Data Processing b	Accounting b
Alexandria	95	67	150	90	200	100
Anoka	60	--	90	--	110	--
Austin	27	--	55	--	55	--
Bemidji	--	21	--	30	--	40
Brainerd	--	15	--	60	--	80
Canby	--	24	--	60	--	60
Duluth	46	60	80	93	80	93
Eveleth	--	16	--	30	--	30
Faribault	--	18	25	30	40	40
Granite Falls	--	19	--	40	--	60
Hibbing	76	--	100	--	100	--
Jackson	--	24	30	48	40	48
Mankato	69	39	95	70	105	85
Minneapolis	33	33	45	45	50	50
Moorhead	25	28	80	40	80	40
Pine City	--	21	--	20	--	20
Rochester	--	11	--	72	--	96
St. Cloud	N/A	N/A	N/A	N/A	N/A	N/A
St. Paul	45	27	73	44	89	70
Thief River Falls	--	10	--	40	--	60
Wadena	--	20	--	18	--	20
Willmar	21	67	35	145	50	150
Winona	--	41	--	128	--	150
	Headcount (1969-70)		Headcount (1976-76)		Headcount (1980-81)	
TOTALS g	146,212		202,864		255,455	
TOTAL PUBLIC POST-SECONDARY	119,075		169,675		219,018	

Appendix H.10. Summary of Enrollment Data and Projections for Minnesota Post-Secondary Education (Concluded)

a Total and Full-Time Equivalent Enrollment by Level in Minnesota Post-Secondary Institutions, Fall 1969. Minnesota Higher Education Coordinating Commission, December 1969.

b Enrollment data is listed only for those Area Vocational-Technical Schools with programs in data processing or accounting. The source of the data is the Division of Vocational-Technical Education, Minnesota State Department of Education.

c These figures are derived by linear interpolation from data for 1969-70 and projections for 1980-81.

d Institutional or system enrollment projections.

e System projections obtained from the Minnesota Higher Education Coordinating Commission.

f Full-time equivalent enrollment projections are estimated by multiplying the total enrollment projections by the ratio of FTE-to-total enrollment for 1969-70.

g The total projected enrollment for all post-secondary institutions in Minnesota (including only the four-year private institutions) were obtained from the Minnesota Higher Education Coordinating Commission.