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UMR 0166

PREFACE

This report presents the evaluation of a method of mechanizing library card catalogs. The method was analyzed by a team of individuals representing a number of different professions, as is characteristic of Operations Research. The team was composed of an industrial Engineer, a Certified Public Accountant, two Mathematicians, a professional Librarian, and a project leader, with training and experience in both Electrical Engineering and Business Administration. In addition, Dr. Robert E. Machol, co-author of "System Engineering,"* served as consultant to the team.

The reader will note that the techniques used in the analysis reflect the diversity in background represented by members of the team. The techniques also reflect the limited objectives of the study. At the request of the sponsor, the study was conducted in such a manner as to provide maximum information concerning card catalog usage to serve as a basis for extending future research in this general area. More sophisticated techniques, such as "Monte Carlo" simulation of the queuing problem encountered, were not justified, although with them more definitive results might have been obtained. It is likely that such techniques will be needed if, in the future, more intensive research is directed toward determining and evaluating other methods of mechanizing library card catalogs.

* Reference 5

1. INTRODUCTION

On October 2, 1957, a proposal was submitted to the Council on Library Resources by a manufacturer of closed-circuit television equipment for design and construction of a prototype, remotely controlled, catalog card viewing system. The proposed "Telereference"* system would permit a researcher to view catalog cards in a central catalog from a remote location by the use of closed-circuit television and a remotely controlled card manipulator.

This idea had considerable appeal to the University of Michigan as a possible means of extending the service of the central catalog to divisional and branch library users, perhaps eliminating the cost of maintaining duplicate card catalogs in library units located outside the General Library Building.

Dr. Frederick H. Wagman, Director of the University Library of the University of Michigan, offered the cooperation of the library staff should the Council on Library Resources desire to study this library system as a test case in determining the feasibility of the proposed equipment.

The Operations Research Department of the University of Michigan Engineering Research Institute was consulted concerning such an analysis. A proposal submitted by this department on December 9, 1957, to the Council on Library Resources resulted in the present study project which commenced on February 1, 1958.

The purpose of this study was to determine the feasibility of the Telereference equipment based on a determination of the amount of equipment needed and any cost savings which might result from installing this equipment in the University Library system at the University of Michigan to replace the card catalogs in divisional libraries. The study was not intended to discover the extent to which scholarship and library use might be facilitated by the availability in each divisional library of the complete catalog in addition to existing divisional library catalogs.

*The word "Telereference" was coined by the Council on Library Resources to describe the proposed equipment.

2. CONCLUSIONS

2.1 SUMMARY

The use of Telereference equipment to replace divisional library* card catalogs in the University Library system at the University of Michigan cannot be justified solely on the basis of savings in direct costs as a result of eliminating divisional library card catalogs. The direct cost savings would cover only approximately 50% of the cost of maintaining the necessary Telereference equipment, not considering the original equipment investment required.

It should be recognized, however, that the objectives of the present study are limited. No attempt has been made to estimate the value of added services which might be provided by Telereference equipment in this application. Although not easily measured, this value could be quite significant, even in view of the relatively high equipment cost. Also, alternative applications for Telereference equipment were not considered. The equipment might provide greater savings in direct costs in various other library applications.

2.2 ESTIMATE OF COST SAVINGS AND AMOUNT OF TELEREFERENCE EQUIPMENT REQUIRED

The cost savings resulting from eliminating card catalogs in all University of Michigan divisional libraries, including the new Undergraduate Library, is as follows: If the divisional card catalogs and shelf lists were both eliminated, the direct cost savings would be approximately \$10,000 per year. If the card catalogs were eliminated but the divisional shelf lists retained, the cost savings would be approximately \$7,000 per year. A summary of these costs in terms of labor, material, and labor overhead is given in Table 1.

These are savings principally in direct labor and materials related to the preparation and the filing of catalog cards for the divisional libraries. In most instances, these savings would not represent a reduction in "out of pocket costs," but would mean that labor now spent on these activities would be free for other tasks.

The amount of Telereference equipment needed to replace divisional card catalogs was estimated in terms of three possible alternative equipment needs: For a sample of 16 of the 43 divisional libraries (including the larger libraries); for the 16 divisional libraries plus the Undergraduate Library; and for the 16 divisional libraries, the Undergraduate Library, and the Public Catalog in the General Library. Estimates of the original costs of the Tele-

*The term "divisional library" is used throughout the report to denote not only divisional but branch libraries, and special departments. A precise distinction was not necessary for purposes of this analysis.

TABLE 1
 SUMMARY OF ANNUAL COST SAVINGS
 THROUGH THE ELIMINATION OF ALL DIVISIONAL
 CARD CATALOGS*

	With Retention of Divisional Shelf Lists			Without Retention of Divisional Shelf Lists		
	Labor	Overhead	Materials	Labor	Overhead	Materials
Cataloging Department	\$3,300	\$290	\$270	\$4,040	\$360	\$320
Divisional Libraries	2,700	360	-0-	4,560	620	-0-
	<u>\$6,000</u>	<u>\$650</u>	<u>\$270</u>	<u>\$8,600</u>	<u>\$980</u>	<u>\$320</u>
			Total			Total
			\$3,860			\$4,720
			3,060			5,180
			<u>\$6,920</u>			<u>\$9,900</u>

* Includes the combined total savings possible from eliminating card catalogs in all "divisional," "branch" and "autonomous" libraries and "special departments" listed in Appendix A, with the exception of the Clements Library, the Law Library and the Flint Branch Library.

reference equipment needed in terms of each of these three alternatives are approximately \$136,000, \$174,000, and \$258,000 respectively. The estimated amounts of equipment needed and associated costs are given in Table 2. Estimates of equipment requirements for the remaining divisional libraries were not made because of the limited nature of the study.

The estimate of the amount of equipment needed was based on a description of the Telereference equipment and on the way the catalog is now used. No attempt was made to estimate how the demands on the catalog might change with the introduction of the equipment. For this reason, the equipment estimates are considered low. Any increase in the use of the catalog or increase in the average time required for an individual to find a given item will increase the amount of equipment needed. In particular, some users will be delayed while card drawers are being brought to cameras, since manual handling of card drawers is assumed (see Section 3).

It is expected that annual maintenance and replacement costs would be at least 10% of the original equipment cost. Since the system as presently designed requires manual handling of card drawers at the cameras, the operating cost of the system must therefore include the cost of two or three members of the library staff to answer calls and bring card drawers to cameras. It was not felt necessary to obtain greater accuracy in estimating personnel operating costs in view of the large discrepancy between equipment costs and the direct savings possible. It is also anticipated that further mechanization would reduce or eliminate the need for such personnel. The present system is not very sophisticated in terms of present-day technical potential. The existing state of automation art would readily permit redesign of the system to provide complete machine handling of both cards and drawers.

Equipment requirements were determined for only 16 of the divisional libraries. The estimate of cost savings was made for 43 divisional libraries, however, because it was more economical to analyze the costs on an aggregative basis than for each library individually. This should be kept in mind in comparing the possible cost savings with the estimated equipment costs shown in Tables 1 and 2 respectively.

The Undergraduate Library was included in the study because it has a status similar to divisional libraries regarding the cataloging of its holdings and maintenance of its card catalogs. The equipment required to replace the Public Catalog in the General Library was determined because it may not be feasible to allow direct public access to the catalog when the Telereference cameras and card manipulator are installed to service a large number of divisional libraries.

2.3 FINDINGS CONCERNING CHARACTERISTICS OF CARD CATALOG USE

Characteristics of card catalog use were studied only to an extent necessary to estimate the amount of Telereference equipment needed. As a by-product of this analysis, several conclusions are suggested concerning the manner in which catalogs are used. These conclusions, however, should

TABLE 2
ESTIMATED AMOUNT OF TELEREFERENCE EQUIPMENT AND INSTALLATION COSTS

	No. of Monitors	No. of Cameras	No. of Card Manipulators	No. of Intercom Units	Estimated Feet of Conduit	Estimated Feet of Coaxial Cable & Wire	Total Cost of Monitors & Control Panels @ \$350	Total Cost of Cameras & Amplifiers @ \$3,000	Total Cost of Card Manipulators @ \$3,500	Total Cost of Intercom Units @ \$100	Total Cost of Conduit & Junction Boxes @ \$1.50 Per Foot of Conduit	Total Cost of Coaxial Cables & Wire @ \$.25 Per Foot	TOTAL COST
16 Division Libraries	26	13	13	26	21,100	32,900	\$ 9,100	\$39,000	\$ 45,500	\$2,600	\$31,650	\$8,225	\$136,975
16 Divisions + Undergraduate Library	35	18	18	35	21,500	36,100	\$12,250	\$54,000	\$ 63,000	\$3,500	\$32,250	\$9,025	\$174,025
16 Divisions, + Undergraduate + Public Catalog	48	30	30	48	21,700	37,400	\$16,800	\$90,000	\$105,000	\$4,800	\$32,550	\$9,350	\$258,500

be interpreted only as suggestive in terms of general application. Further study of these use characteristics might be quite fruitful in research to improve catalog service with or without mechanization.

The number of users at each catalog studied varied considerably from hour to hour during the day. The peak rates of arrival to the catalogs appeared to occur a few minutes after the hour in almost all libraries studied. In addition, a peak demand on the catalogs occurred about mid-morning and/or about mid-afternoon at the majority of libraries. The peak rates of arrival (over a ten-minute interval) were generally 2-3 times greater than the average arrival rate for a whole day, and the duration of peaks seldom exceeded ten minutes.

The distribution of arrival rates to all catalogs studied corresponded closely to the theoretical mathematical "Poisson" distribution. Similarly, the distribution of holding times (the lengths of time a person uses a catalog) corresponded closely to the lognormal distribution, which can be approximated by a negative exponential frequency distribution.* There is evidence that the average holding time at each catalog can be expressed as a logarithmic function of the number of cards in the catalog.

Due to the specific objectives of the study, and the corresponding limited amount of data collected, these findings represent only tentative general conclusions. It is believed that these (and other) characteristics of catalog use should be investigated more thoroughly in future research concerning methods of reducing costs and improving the card catalog service.

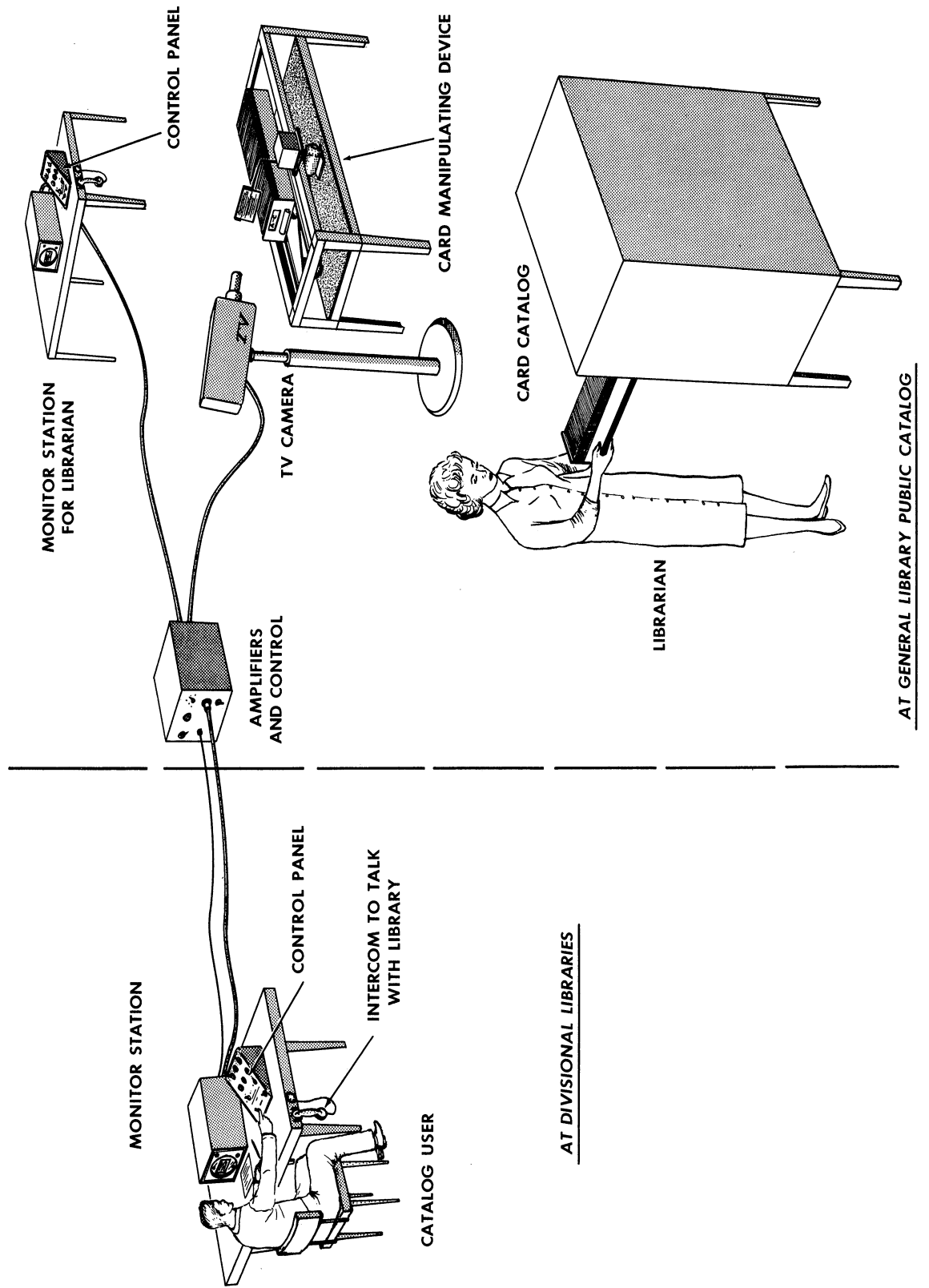
3. THE TELEREFERENCE SYSTEM

The following description of the Telereference system is based on a proposal received by the Council on Library Resources during the fall of 1957 from a manufacturer of closed-circuit television equipment (see artist's conception, Fig. 1)

The Telereference system would permit a researcher to search through cards in a central catalog from a remote location by use of closed-circuit television and a remotely controlled card manipulating device which would operate with unmodified (except for removal of rod) catalog drawers with 3 x 5 inch cards. The catalog user would request to see certain subject or title cards by means of a two-way audio link. The librarian would locate the catalog drawer containing the desired information and place it in the card viewer. The researcher would read the index tabs on a television screen and open the cards at the desired index point by

* Queuing problems involving random fluctuations can, in general, be readily solved only when the arrival rates and service times can be represented by the Poisson and exponential distributions respectively. The lognormal distribution may be even more closely approximated by an Erlang-2 channel (reference 8), but in the present case the exponential approximation was adequate.

Fig. 1. Artist's Conception of the Teleference System



means of a remote control switch. The first catalog card after the index tab would automatically appear on the television screen. The catalog user could cause the cards to be turned one at a time; or, by holding a lever in one position, the equipment would automatically and continuously turn cards for scanning at a rate of approximately one per second until the desired information is located. The card could then be stopped for longer viewing. The user may also return to cards already viewed and repeat the search or cause the drawer to be moved swiftly to another index tab section. It would be possible for the librarian to view the same picture seen by the researcher and even take control to help locate the required information. A two-way conversation could be held continuously to aid the search.

The cost of card manipulators is estimated to be \$3,500 per unit if produced in production lots of 100 units. The combined cost per unit for a monitor (television receiver) and control panel for the card manipulator in units of 30 or more is estimated to be \$350.00. The unit cost of a television camera, lens, and amplifiers, standard production items, is estimated to be \$3,000. The audio communications (intercom) equipment required with each monitor is estimated to cost \$100.00 per unit.

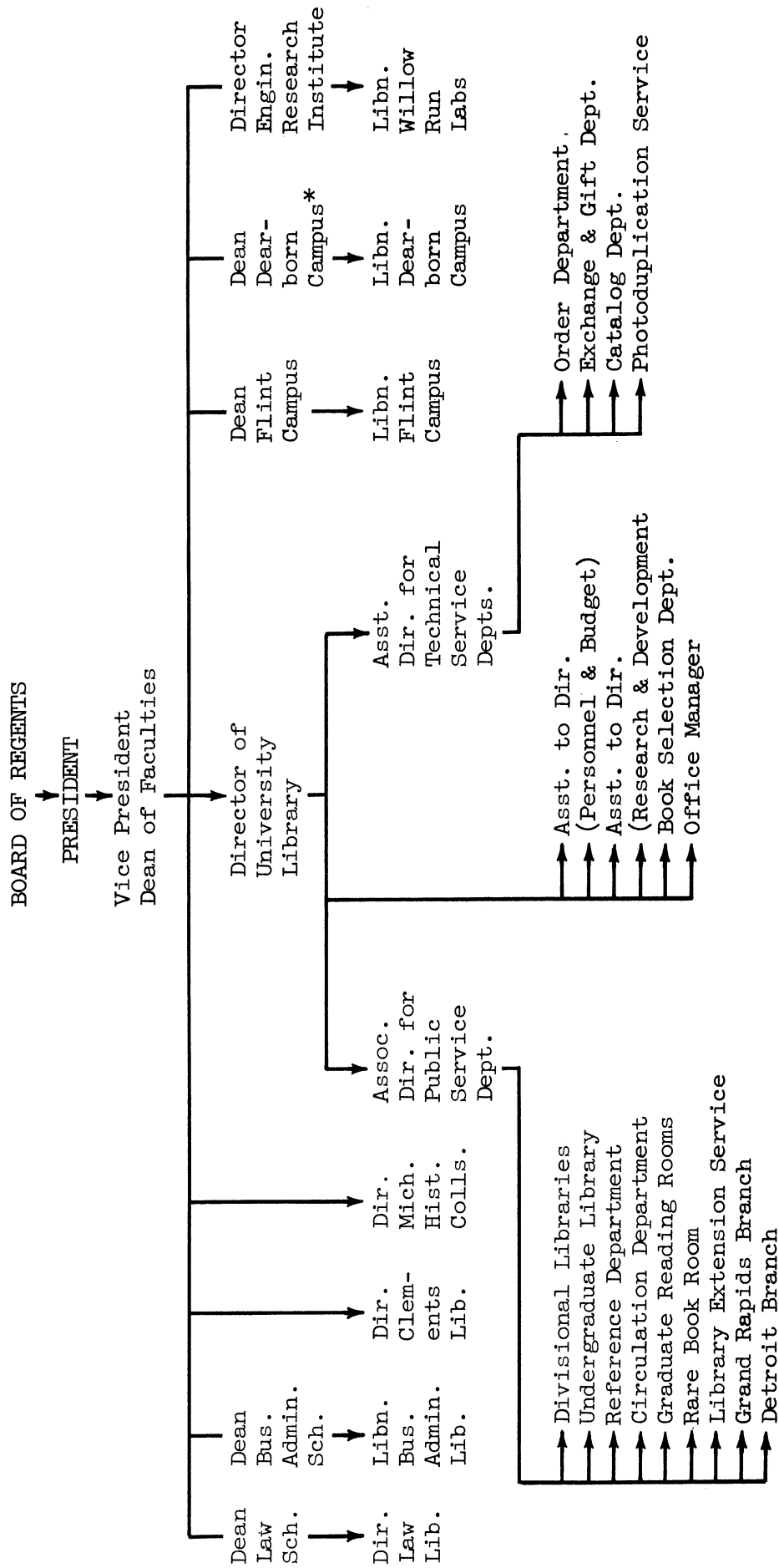
In addition to these costs, the cost of installation has been estimated to be \$1.50 per foot for labor and materials for installing conduit and junction boxes in existing tunnels between buildings on the U of M. campus, plus \$.25 per foot for the necessary coaxial cable and audio wires.

4. THE UNIVERSITY OF MICHIGAN LIBRARY SYSTEM

There are many libraries on the University of Michigan campus, most of which are the administrative responsibility of the Director of the University Library system. The University Library system is responsible for the General Library, the Undergraduate Library, the North Campus storage annex, and more than 30 divisional libraries and special departments. Libraries which do not come under the administrative responsibility of the University Library system include the Law Library, the Clements Library (Rare Americana), the Business Administration Library, the Michigan Historical Collections, the Flint Campus Library, and the research library located at the Willow Run Laboratories. Altogether there are some 43 divisional libraries associated with the University of Michigan, most of which are located in academic buildings on the campus within 100 to 1,300 yards of the General Library Building. However, one divisional library is located on the new North Campus in Ann Arbor, some two miles from the General Library, and there are special branch libraries in Flint, Detroit, Grand Rapids, and elsewhere. A simplified organization chart of the University of Michigan Libraries is shown in Fig. 2.

It is to the divisional libraries located on the Ann Arbor campus that our attention has been directed in studying the feasibility of the Tele-reference equipment. With the exception of the Business Administration Library, which uses the catalog and order service of the University Library system, the libraries which do not come under the administrative responsibility of

Fig. 2
SIMPLIFIED ORGANIZATION CHART
UNIVERSITY OF MICHIGAN LIBRARIES



* Projected

the University Library system were not included in the study.

The ordering and cataloging functions in the University Library system are centralized in the Order and Catalog Departments located in the General Library Building. All purchases of books, serials, etc., and the cataloging of incoming material for all libraries in the University Library system are processed through these two departments. Items received by gift and exchange are processed by the Exchange and Gift Department before being sent to the Catalog Department.

Each divisional library has a card catalog and a shelf list of its holdings. The newly completed Undergraduate Library, which is located on three floors of the Undergraduate Library Building, has four card catalogs; a main catalog for all holdings, and a floor catalog of the holdings on each of the three floors. With the exception of the Business Administration Library, libraries which are not under the administrative jurisdiction of the University Library system maintain their own card catalogs. In addition to the divisional library card catalogs, the University Library system maintains a Public Catalog in the General Library of the holdings of all libraries of the University of Michigan. The cataloging is, however, complete only for the holdings of the University Library system; only main entry cards are filed here for holdings of the autonomous libraries. This catalog contains some 3,125,000 cards which are housed in approximately 3,800 drawers. In addition, several other catalogs are maintained principally for use by members of the University Library staff, especially the Order and the Catalog departments. These include the Official Catalog, the Depository-Union Catalog, the Union Shelf List, and the Serials Check List. Further discussion of the functions of these catalogs is given in Appendix A.

5. PROCEDURE FOR ESTIMATING COST SAVINGS

The possibility of significant cost savings from the introduction of the Telereference equipment in eliminating divisional card catalogs was one of the principal motivating factors behind the present study. Preliminary investigation revealed various cataloging costs associated with divisional libraries, but only a fraction of these costs would be saved. Only those direct incremental costs which would be eliminated if the divisional library catalogs were eliminated were considered in this study.

The cataloging function for all libraries in the University Library system is centralized in one catalog Department as mentioned in Section 4. Costs related to the maintenance of divisional library catalogs and shelf lists occur in the Catalog Department, and in the divisional libraries. The cost savings which would result in each of these were estimated on the basis that the procedures now used would be eliminated or modified by the installation of Telereference equipment. The costs were calculated in terms of the direct labor, direct labor overhead, and materials involved. The cost of supervision was not included in the estimate except in those instances where the supervisor was directly involved in certain tasks. Since it may be

desirable to retain the shelf lists in divisional libraries even if Tele-reference equipment were installed, the cost associated with both alternatives, if retained and if not retained, was estimated.

The costs in the Catalog Department were analyzed by types of acquisitions (which include New Titles, Other Copies, Added Copies and Added Volumes)* and in terms of costs associated with acquisitions and transfers. These costs were broken down into the costs of Xeroxing, typing and stamping, proofreading, material and filing which would be saved if the Telereference equipment were installed. The details of this analysis are shown in Appendix B.

The cost analysis was based upon the number of cards involved in the various operations and upon the amount and different types of labor and materials involved in their preparation. Statistical data concerning acquisitions was obtained from the Annual Report of the Director of the University Library for 1956-57 and from a statistical summary of the Catalog Department operations for the same University year. The statistics taken from the annual report were revised to account for the effect of the Undergraduate Library, which is expected to reach a size of 75,000 volumes by the end of this year. With this exception, the statistics for the 1956-57 University year were used as a basis for estimating the cost savings.

Estimates of the labor involved in various procedures were obtained from work-measurement statistics obtained from the Catalog Department, from direct observations, and from limited work-measurement studies. The direct labor rates were based on the salaries plus direct payroll overhead. This information was obtained from the library personnel officer for those groups of people involved in the pertinent cataloging procedures. The method of computing hourly rates and overhead rates is shown in Appendix B, Exhibit B-1.

6. PROCEDURE FOR DETERMINING AMOUNT OF TELEREFERENCE EQUIPMENT NEEDED

6.1 INFORMATION REQUIRED TO DETERMINE EQUIPMENT REQUIREMENTS

The equipment needed to replace divisional card catalogs will depend on the characteristics of the equipment and on the characteristics of card catalog use. Information concerning the characteristics of the Telereference equipment was limited to the description of the equipment as presented in Section 3 above. Based on this description, the analysis was limited essentially to determining the characteristics of use of the system (rate of demand and use-time). These characteristics were then used in determining the requirements for equipment needed to replace card catalogs in divisional libraries.

The minimum amount of information needed to estimate equipment require-

* See Appendix B, Section 3 for meaning of these terms.

ments includes: (1), the distribution of arrival rates to the catalogs; (2), the distribution of length of catalog use-time of individual users; and (3), the average demand and the magnitude and duration of peak demands on the card catalogs. These characteristics were investigated for each library catalog studied by observing the use of the catalogs during a two-week period in March 1958. The composite system demand (for all library catalogs combined) was recorded on one day during a three-hour period when the peak on the system would occur.

For economy of effort, only 16 of the divisional libraries in the University Library system were selected to be studied. In addition, however, the four card catalogs in the Undergraduate Library and the Public Catalog in the General Library were also studied. Strictly speaking, the Undergraduate Library is not a divisional library, but it contains card catalogs which are serviced by the Catalog Department in the same manner as divisional card catalogs.

The Public Catalog in the General Library was studied because if Tele-reference equipment is used to replace card catalogs in divisional libraries, it is quite likely that the installation of cameras and card manipulators at the Public Catalog will interfere with the direct use of the catalog by the public. This will almost certainly be true if some form of mechanized equipment is used to bring the card drawers to the card manipulating devices at the cameras. Under such circumstances, it would most likely be necessary to eliminate direct public access to the Public Catalog and provide Telereference equipment for normal users of the Public Catalog as well. Incidentally, if this were done, the catalog itself could then be placed in some less expensive floor area.

6.2 DATA COLLECTION PLAN

The data collection was organized into three phases. First, a questionnaire was sent to all divisional libraries early in the study period requesting (among other things) estimates of the occurrence of the peak use of each catalog by hour of the day, by day of the week, and by week of the semester. From these estimates, the second phase of the plan was then designed to record the peak demands on each individual library to determine the demand (distribution of inputs) and use (distribution of holding times) at each of the various catalogs, and to determine approximately when the composite use of all catalogs would combine to form a system peak. The third phase of the plan was devoted to measuring the combined system peak by recording simultaneously the demand on each of the catalogs studied during the three-hour period when the system peak was expected to occur based on the data taken the previous week.

Data were recorded during a two-week period in March using approximately 65 University students. Since the project was initiated at the beginning of the second semester, the collection of data was delayed as long as possible so that the use of the library would be approximately normal during the data collection period.

Data were collected from every library for at least one full day and for at least one hour (estimated to be the peak hour by the librarians) for every day of one week. In addition, data were collected from all libraries for the three-hour period during the second week when the system peak was estimated to occur. The length of the study period did not permit enough sampling to determine seasonal peaks. However, the library staff estimates that the level of catalog use during the two-week period of data collection was slightly above average in terms of seasonal variations, but well below the peak level which occurs during the preparation of term papers just after the middle of the semester.

The sampling thus provided a rough estimate of the day-to-day variation in demand on each catalog studied, and a better estimate of the hour-to-hour variation. Essentially no information was obtained via sampling concerning the week-to-week or the seasonal variations in demand on the catalog. Further detail concerning the data collection plan, including exhibits of the questionnaire and data sheets used, is presented in Appendix C.

6.3 CALCULATION OF NUMBER OF MONITORS AND CAMERAS REQUIRED

The number of monitors required in each of the divisional libraries, in the Undergraduate Library, and in the Public Catalog of the General Library was based on the arrival rates and holding times observed at each of the catalogs at the time of heaviest use of that catalog. Two design criteria were used: (1), the average waiting time to obtain a monitor should not exceed one minute; and (2), during the peak 10-minute period for each library, a user would not have to wait more than 5 minutes to obtain a monitor.* A detailed discussion of the method of calculation is given in Appendix D.

In estimating the number of monitors required, it was assumed that when a person obtained a monitor it would require zero time to obtain a camera and card manipulating device, and also zero time to have a card drawer brought to the card manipulating device at the camera. While these assumptions clearly lead to underestimation of the equipment required, no better assumptions were available. When actual times are known, the data in this report permit simple recomputation of the extra equipment required. It was further assumed that any camera can obtain access to any drawer in the Public Catalog. Since a camera is associated with a card manipulator, the number of card manipulators needed is assumed to equal the number of cameras.

The number of cameras required was calculated by determining the demand

* This criterion is more conservative than it appears, for several reasons: peak demand occurs only about four times a week; this demand is short-lived and the queues do not have time to build up to the extent predicted, and monitors cannot be supplied in fractional amounts (e.g. if with four monitors the peak delay would be 7 minutes and with 5 monitors the peak delay would be 2 minutes, the 5-minute criterion would require choosing the latter). Hence with a 5-minute criterion, only a small fraction (approximately 1%) of catalog users would wait more than 2 or 3 minutes.

on each individual catalog during the 20-minute interval from 3:00 to 3:20 on Monday, March 17, 1958, when the composite demands of all the catalogs formed the system peak. The use of the catalog in each of these libraries was recorded simultaneously at this time. The composite demands for monitors at each of the catalogs studied thus also represents the composite demand for cameras during the system peak. This is the largest demand for cameras to be expected at any time. Based on this composite demand during the system peak, a number of cameras was selected such that the probability of a person having to wait for a camera after having obtained a monitor would be in the order of .02*. The nature of the expected demand for cameras during the system peak is shown in Fig. 3. This curve represents a theoretical estimate of the probability of needing more than a certain number of cameras, X, when 30 cameras are provided, and 20.4 cameras are needed on the average (see Fig. 3). The probability of needing 30 cameras is very low, while the probability of needing 10 or fewer cameras is very high (near unity).

Estimates of the amount of Telereference equipment needed and costs of installation were made in terms of three alternatives:

1. Installation in 16 divisional libraries alone.
2. Installation in 16 divisional libraries and the Undergraduate Library.
3. Installation in 16 divisional libraries, the Undergraduate, and General Libraries (Public Catalog).

These estimates are given in Table 2, Section 2. The number of intercom systems was assumed equal to the number of monitors. The estimates of cable required were scaled from a map of the campus.

7. FINDINGS CONCERNING USE OF CARD CATALOGS

As mentioned in Section 6 above, three characteristics of card catalog use were studied. These included the characteristics of arrival rates, catalog holding time, and peak load demands on the card catalogs. Figures 4A, 4B, 4C and 5A show the variations in load demands on four of the catalogs studied for the day during which data were recorded all day in each library. The data shown in Figures 4A, 4B and 4C are representative of the typical small, medium, and large divisional library catalogs studied. The data plotted represent the number of arrivals in 10-minute intervals from 10 a.m. to 8 p.m. exclusive of the lunch and dinner hours, during which time data were not recorded because of the low use. The average number of arrivals per 10-minute interval during the day is shown on each of these figures. The peaks vary sharply above the average rate of arrival, but the duration of peak load demands is in general short-lived. The highest peaks observed did

* For method of calculation see Appendix D, Section 4.

Fig.3.
Probability of Needing
More Than x Number of Cameras
During System Peak

(Based on 30 Cameras Provided; $\rho = 20.4$)

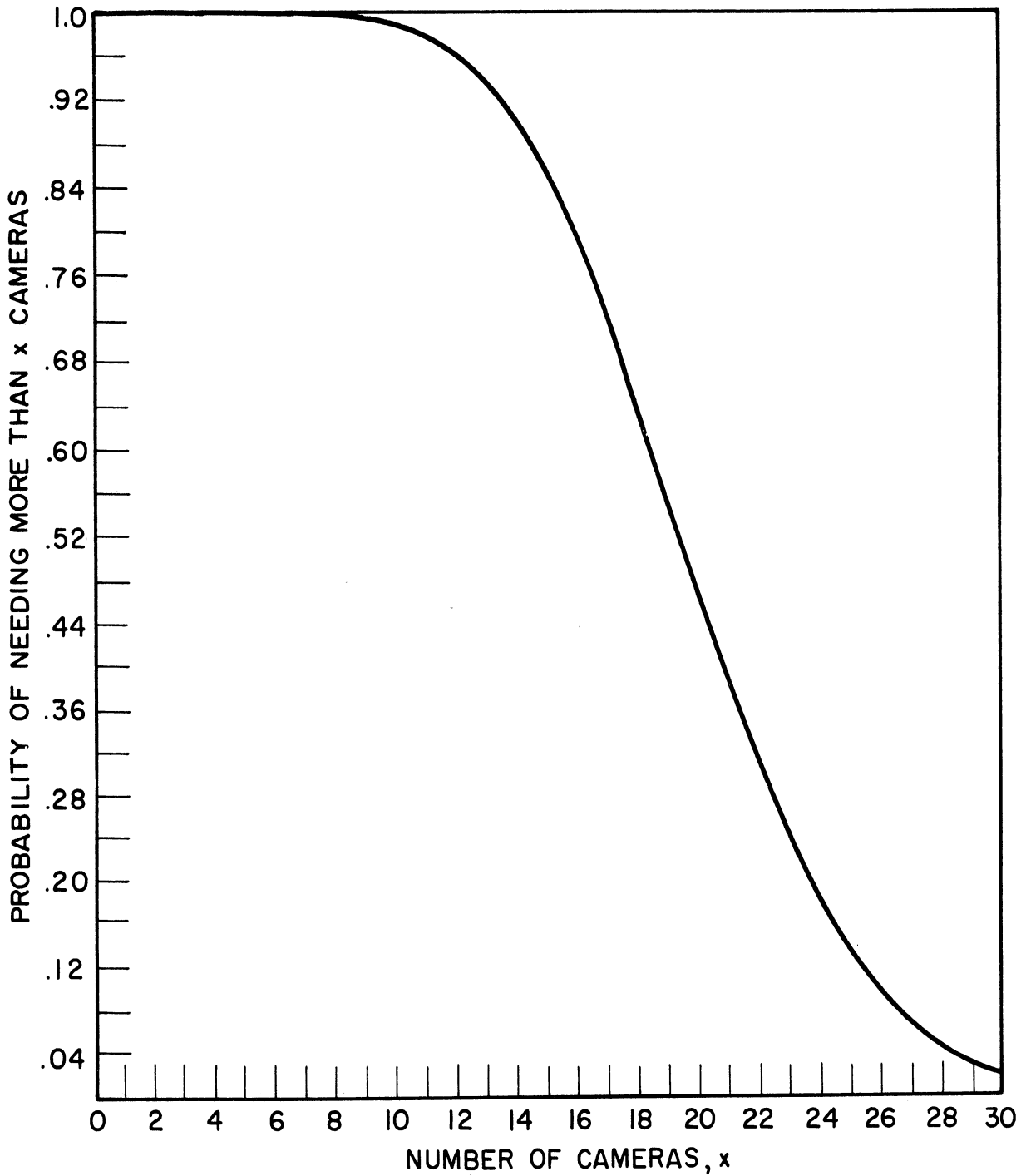


Fig.4.A.
Number of Arrivals to Card Catalogs
During 10 - Minute Intervals, 10 A.M. TO 8 P.M.

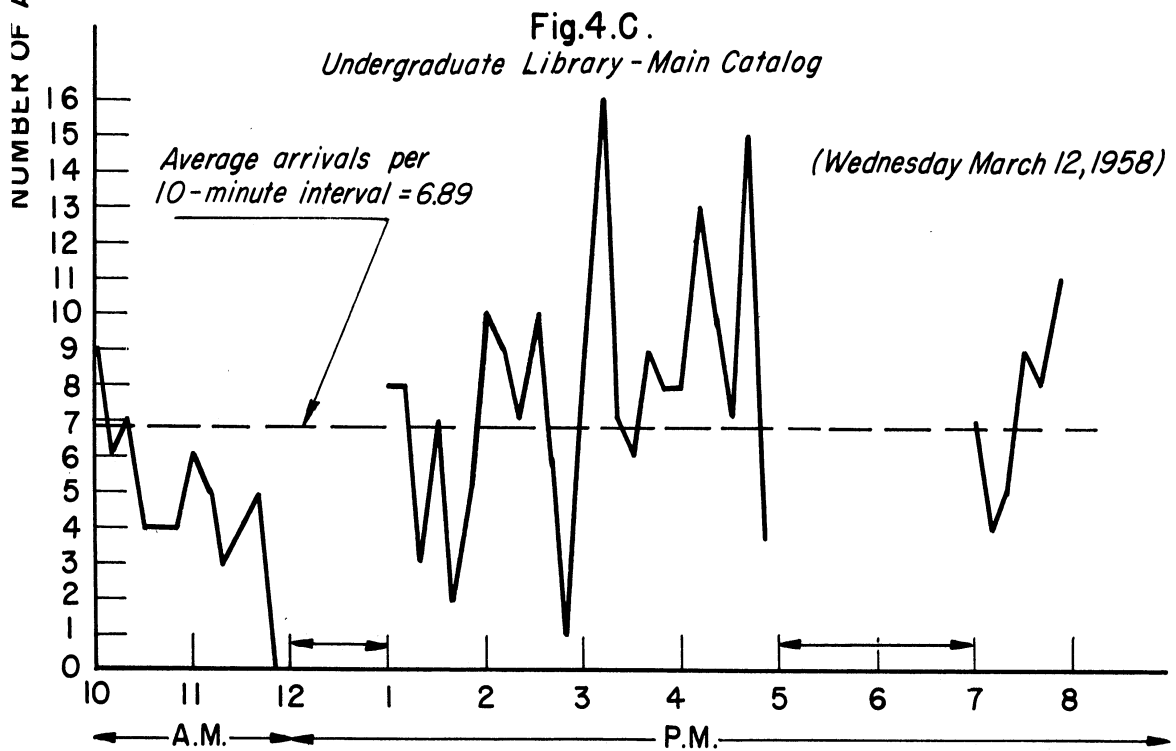
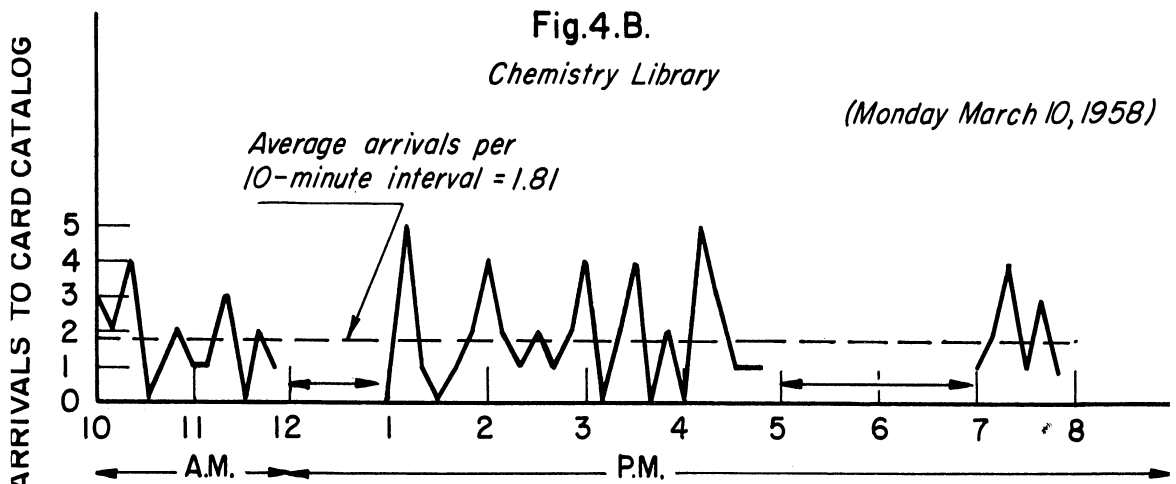
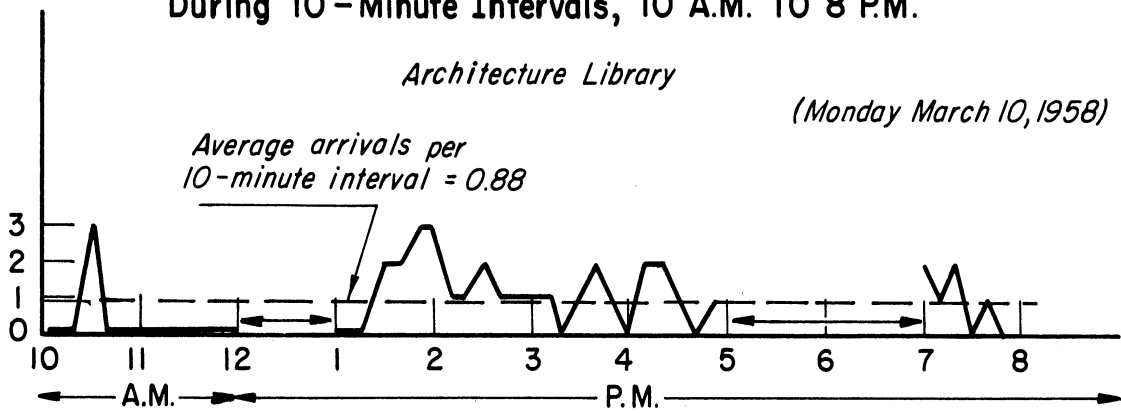


Fig. 5 . A.

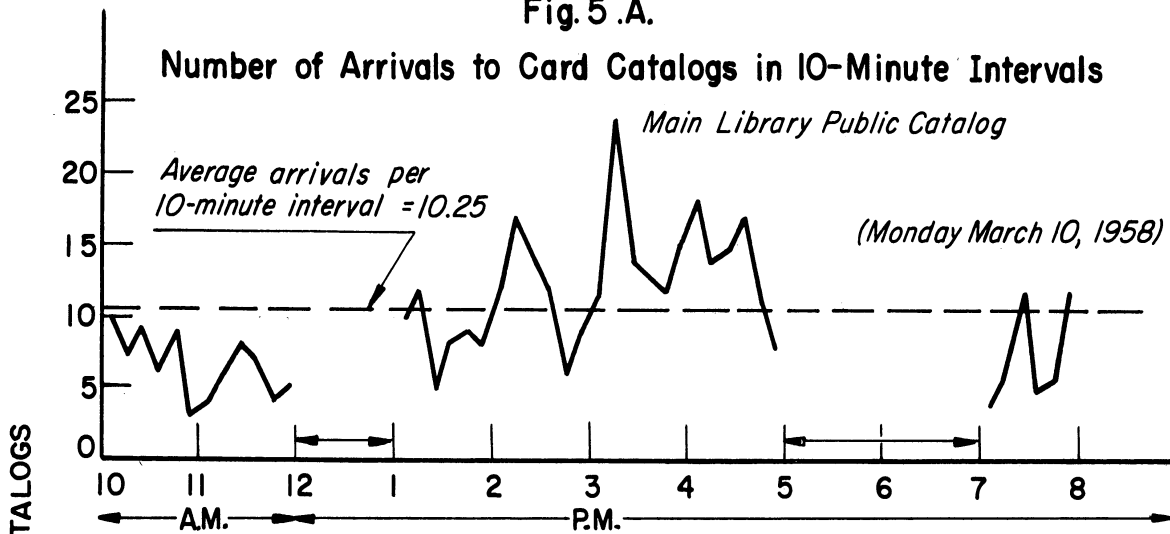
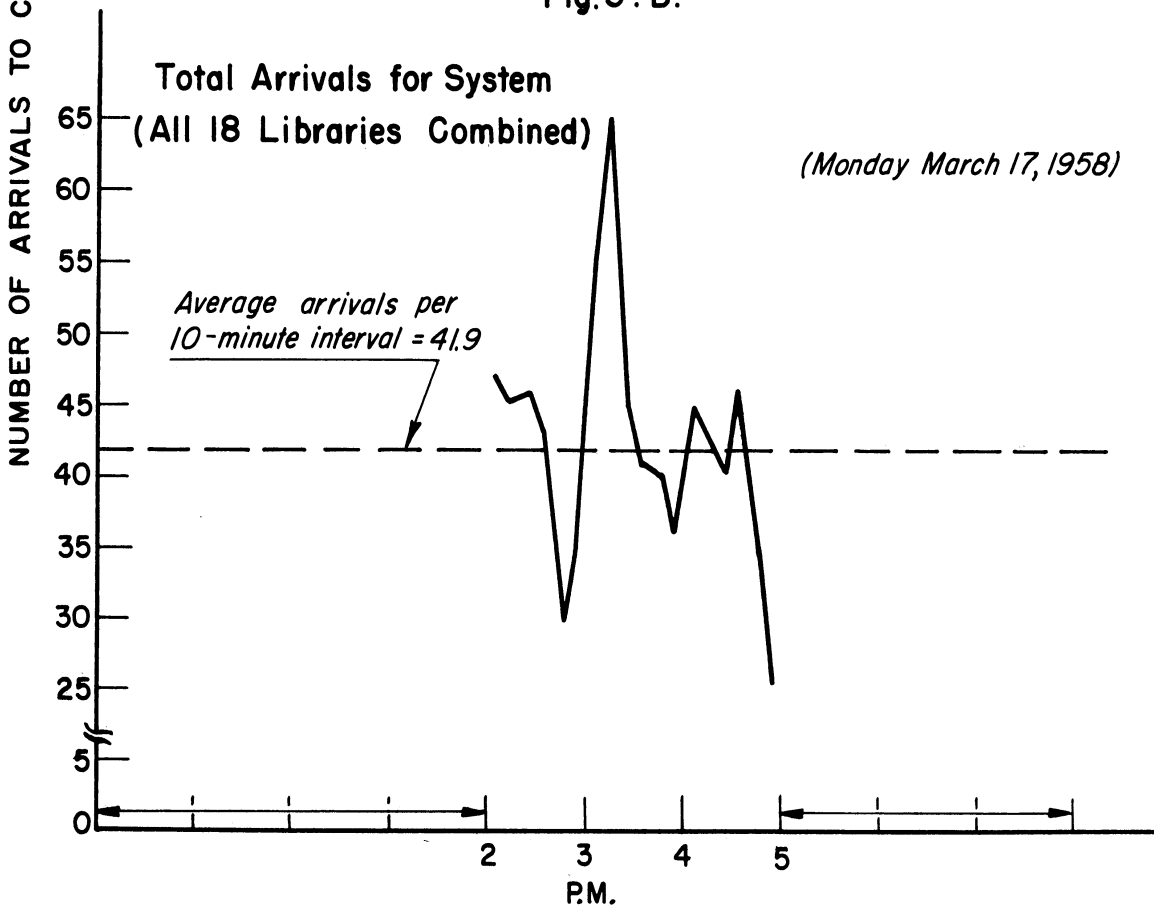


Fig. 5 . B.



not have duration longer than 10 minutes. The peak demand on the system, (including the 16 divisional libraries studied plus the Undergraduate Library on March 17 and the Public Catalog in the General Library) is shown in Fig. 5B. The heaviest use occurred between 3:00 and 3:20 in the afternoon. During this 20-minute interval, there were 120 arrivals to all catalogs observed, for an average of six arrivals per minute to the system.

The load demand on the Public Catalog in the General Library on Monday, March 10, 1958 is shown in Fig. 5A. Figures 5A and 5B together illustrate that the variations in peak load demands on the system correspond quite closely to the variations in peak load demand observed at the Public Catalog the same day (Monday) the week before. Approximately 50% of the system demand is composed of the demand on the Public Catalog in the General Library.

Table 3 shows, for each library catalog studied, the peak arrival rate during a 10-minute interval, the average arrival rate over the 7-hour period during the day when data were recorded for the entire day, the average holding time* of each catalog based on all the observations recorded during the two-week period, the number of volumes in each library, and the estimated number of cards in each card catalog studied. The peak load demand on each library is considerably greater than the average load demand during the entire day, as shown in Figures 4 and 5. As would also be expected, the average and peak rates of arrival are larger for the larger catalogs. Likewise, the average length of time spent using a catalog varies somewhat proportionately with the logarithm of the catalog size. The Public Catalog, which has 3,125,000 cards, was observed to have the longest average holding time of 5.3 minutes, and also had the highest peak and average arrival rates.

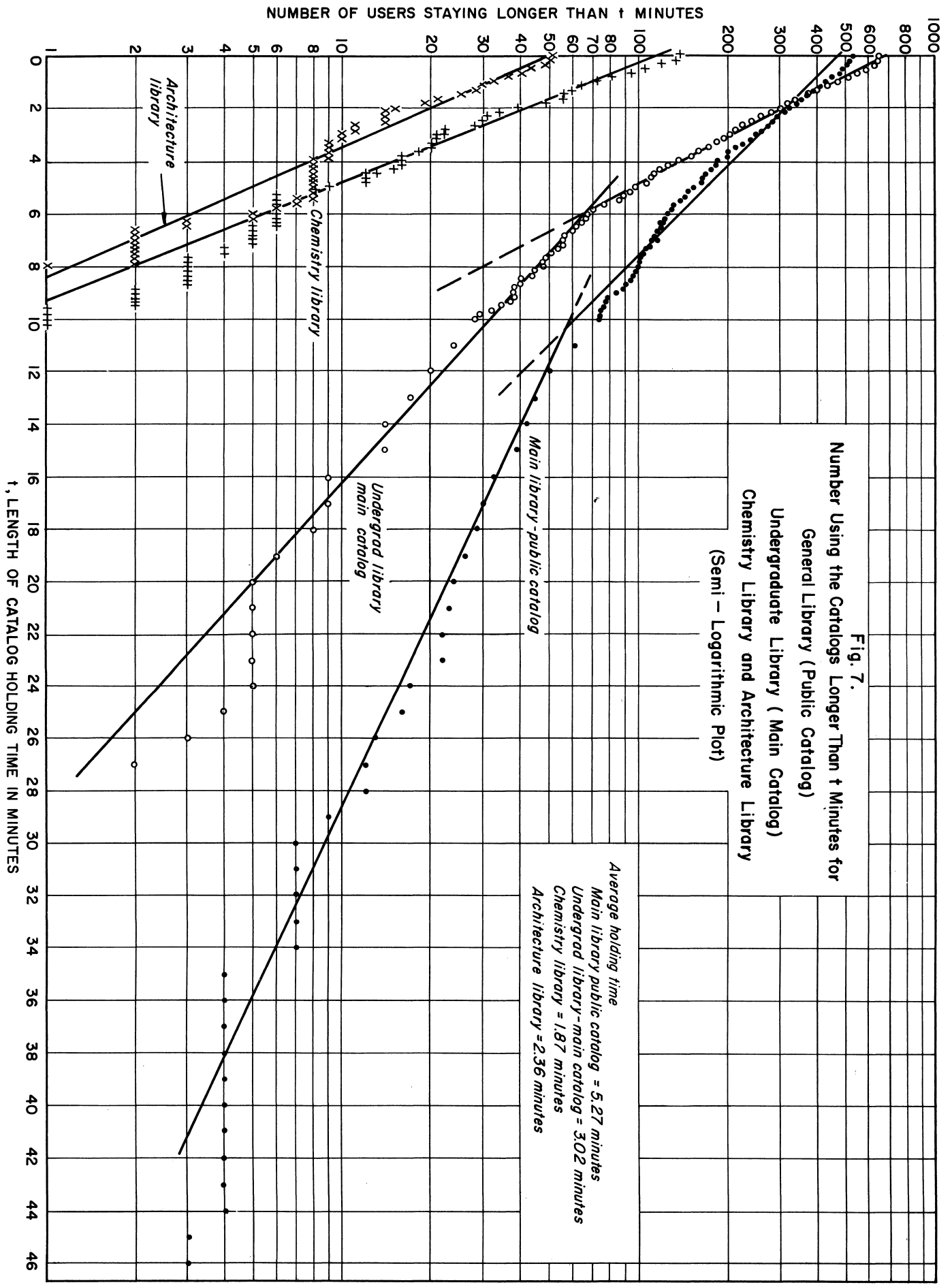
The fact that each of these three distributions can be approximated very closely by a straight line as shown in Fig. 6 is a significant finding. This means that the distribution of the time between arrivals to catalogs follows the mathematical form of a negative exponential function. From this finding, then, we know that the distribution of arrival rates to the catalogs takes the form of a Poisson distribution. Since the Poisson distribution represents a distribution of independent events it was expected that the distribution of arrival rates to the catalogs would take the form of the Poisson distribution. Our hypothesis is thus confirmed. The "goodness of fit" of the experimental observations recorded in the Undergraduate Library to the theoretical negative exponential frequency distribution was further tested by the Chi-square technique as shown in Appendix D, Section 2.

The distributions of the length of times people use the catalogs (holding times) in the Architecture, Chemistry, Undergraduate and General Libraries is shown in Fig. 7. This is a semi-log plot similar to Fig. 6 showing intervals of catalog use time on the horizontal scale, and the number of occurrences greater than each time interval on the vertical scale. For instance, all of the catalog users use the catalog for a time interval longer than zero. Very few used the catalog for a time interval longer than 7 minutes in the Archi-

* Catalog "holding time" was measured from the time a person first touched a catalog drawer until he closed the last drawer used.

TABLE 3
SUMMARY DATA CONCERNING CATALOG USE AND LIBRARY BUILDINGS FOR LIBRARIES
INCLUDED IN THE STUDY

Library	(1) Arrival Rate During Peak 10 Minutes (Per Minute)	(2) Average Arrival Rate During One Full Day (Per Minute)	(3) Average Arrival Rate For All Data Recorded (Per Minute)	(4) Average Holding Time For All Data Recorded (Minutes)	(5) No. of Volumes	(6) Estimated No. of Cards
Architecture	0.3	0.088	.074	2.356	15,216	39,000
Astronomy	.2	.029	.029	2.340	15,740	10,000
Bureau of Government	.3	.100	.098	2.077	39,532	36,800
Business Administration	.4	.098	.105	2.900	113,175	90,000
Chemistry	.3	.181	.157	1.873	23,421	108,000
Dentistry	.2	.019	.031	1.205	17,742	21,050
Education	.6	.179	.159	2.415	24,596	48,700
Engineering	.9	.337	.312	2.446	126,807	216,000
Fine Arts	.4	.048	.061	1.715	12,000	36,000
General Library (Public Catalog)	2.3	1.025	1.010	5.269	1,293,867	3,125,000
Mathematics	.7	.096	.133	2.155	28,639	65,000
Medical	.6	.157	.148	3.438	115,087	100,000
Natural Resources	.8	.211	.232	2.904	81,977	180,000
Physics	.4	.072	.072	1.942	18,322	15,750
Public Health	.4	.163	.098	2.017	10,689	19,000
Social Science	.8	.242	.250	2.101	10,260	48,000
Transportation	.1	.039	.042	3.566	117,913	87,000
Undergraduate-Main	1.4	.689	.800	3.022	62,000	214,000
First Floor	.4	.109	.093	1.638		
Second Floor	.7	.159	.180	1.395		
Basement	.5	.205	.220	1.345		



ture and Chemistry Libraries, and very few used the Undergraduate Main Catalog or the Public Catalog in the General Library more than 25 minutes. The distribution of catalog holding time in the smaller libraries, i.e., the Architecture and Chemistry Libraries, can be approximated with one straight line as shown on Fig. 7. The distribution of catalog holding times at the larger catalogs, i.e., the Undergraduate Main Catalog and the Public Catalog in the General Library, appears to be better approximated by two straight lines. This suggests that there are two classes of users, "populations" of users, or methods of use of the larger catalogs as opposed to only one method of using the smaller catalogs. This hypothesis can be supported on the logical grounds that the smaller divisional library catalogs are used primarily for finding one or two books and are not used for extended bibliographical searches, whereas the larger catalogs are useful for both tasks.

In terms of the mathematical form of the distributions, it would appear that there are two populations, both with truncated negative exponential form, one with a short mean time (the book searchers) and one with longer mean time (the bibliography searchers). The observed data are possibly the sum of the two.

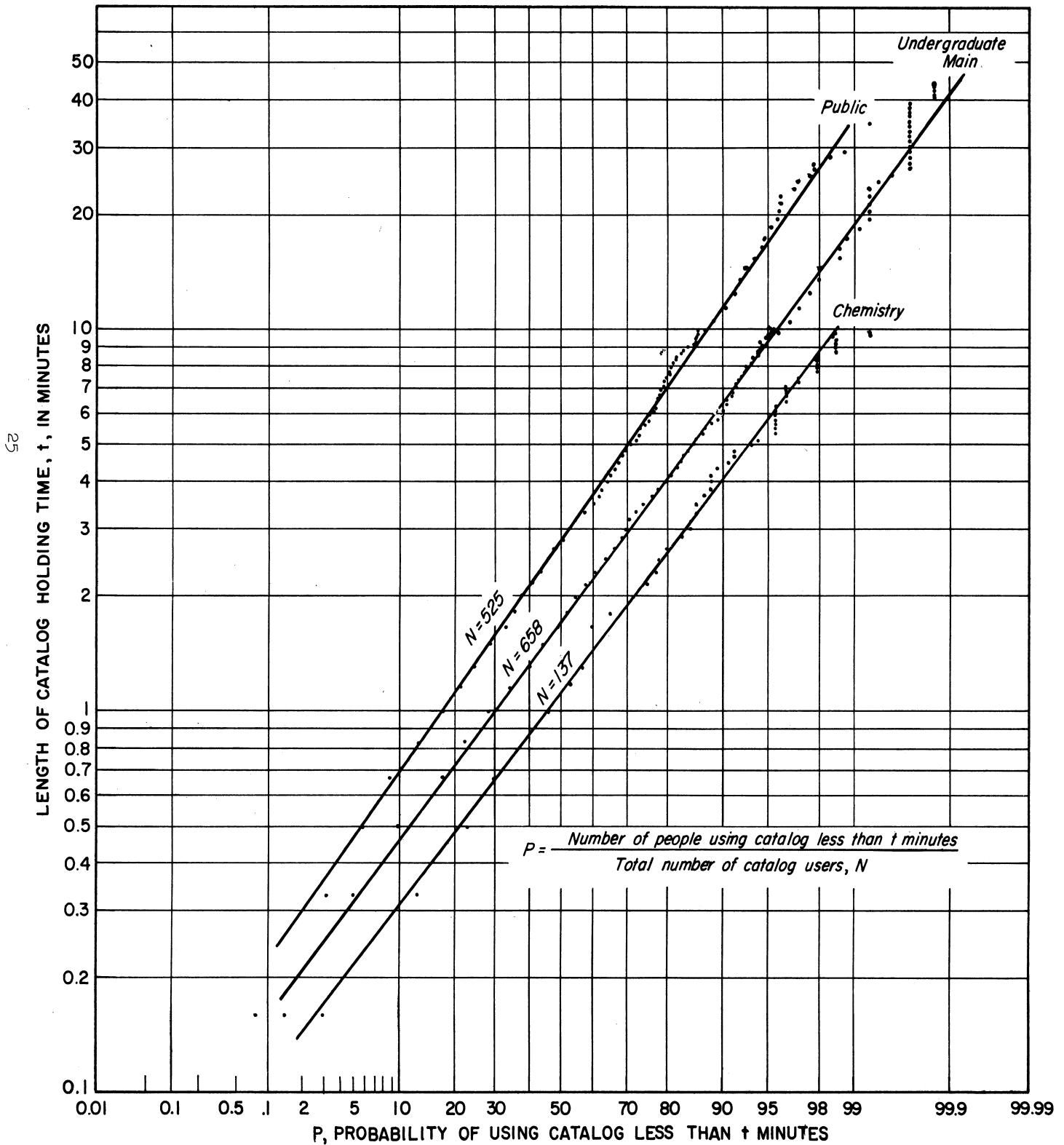
Examination of the characteristics of these distributions using the Chi-square test for "goodness of fit" indicated that the holding time distribution for various library catalogs could be fitted over most of the range of the data with a single, non-truncated negative exponential distribution*. As an approximation then for purposes of the queuing theory calculation of the number of monitors and cameras, a single non-truncated exponential distribution with the observed mean was used to represent the holding time distribution. This type of approximation is known** to yield excellent results.

Further use of the Chi-square test, however, was then made to determine the comparative goodness of fit of the lognormal distribution to the observed data. The result of this investigation revealed that the observed data conforms much more closely to the lognormal distribution than to the negative exponential. This finding is presented graphically in Fig. 8. The holding time data recorded at the General Library (Public Catalog), Undergraduate Library (Main Catalog), and Chemistry Library Catalog (shown previously in Fig. 7) are shown again in Fig. 8 using a logarithmic-probability plot of the data in cumulative form. Data from the Architecture Library shown in Fig. 7 were omitted because they could not be shown clearly on the same graph. In Fig. 8 the length of catalog holding time t , in minutes, is shown on the vertical (logarithmic) scale, and the probability of using a catalog less than t minutes is shown on the horizontal (probability) scale. When plotted in this manner, the lognormal distribution appears as a straight line. It can be seen that the data from all three libraries can be approximated very closely with straight lines. By comparing Figures 7 and 8, it is easily seen that the data correspond more closely to the lognormal distribution than to the negative exponential distribution of users as discussed above.

* See Appendix D, Exhibit D-2.

** Goode & Machol, reference 5, pages 352-354.

Fig. 8
 Probability of Using Catalogs Less Than t Minutes
 for
 General Library (Public Catalog)
 Undergraduate Library (Main Catalog)
 and Chemistry Library
 (Logarithmic - Probability Plot)



Since a variate, which can be defined as the product of a number of more elementary variates, tends to be lognormally distributed,* this finding suggests that there may be characteristics of the information structure in the catalog itself which give rise to the lognormal distribution of holding times. Aitchison and Brown** point out that the "theory of breakage" attributed to Kolmogoroff,*** which offered to explain the occurrence of lognormal distribution in the size of particles of ore which had been crushed by (repeated) natural or artificial processes, can be directly related to a theory of classification. When a great many items are classified using some homogeneity principle, the number of items in a class often is distributed lognormally. Since a certain set of consistent classification rules is carefully followed in library cataloging operations, this suggests that the lognormal distribution of holding times observed may be a resultant primarily of the structuring of information in the catalog. Furthermore, since the data from small as well as large catalogs takes the form of the lognormal more closely than that of the negative exponential distribution, the distribution of holding times may be influenced more strongly by the structure of the catalogs than by the existence of two "populations" of users, as conjectured above. Unfortunately, more definitive conclusions cannot be made on the basis of the present study. It appears that further research concerning the effect of the organization and presentation of information in catalogs may prove valuable in efforts to provide improved catalog service, even without mechanization of catalogs. The present finding suggests that it may be possible to evaluate analytically various catalog structures in an effort to provide improved service to library users concerned with different subject fields.

8. RECOMMENDATIONS AND GENERAL COMMENTS

Since the present study was directed only to the evaluation of the Tele-reference system in one possible application and in terms of direct cost savings, it should not be inferred that the equipment has no feasible application in library operations. The value (to the user) of the added services which might be provided by the equipment should, in fact, be determined before a final judgment is made even in the present case. In commenting on the preliminary draft of the present report, Dr. Richard L. Meier**** of the Uni-

* Aitchison & Brown, reference 1, pages 20-27.

** cf. Aitchison & Brown, reference 1, pages 26-27.

*** Kolmogoroff, reference 7, page 99.

**** During the period of the present study, Dr. Meier has been independently studying the University Library system as an example of a complex social organization in connection with a basic research program being conducted by the University of Michigan Mental Health Research Institute.

versity of Michigan Mental Health Research Institute said, "It appears to me that a calculation of returns which requires considering the library as a business firm is not sufficient for a tool device like the Telereference system. The profits from its use are only to a small extent reflected in the library operations themselves. The primary benefits are registered in the expediting of research and higher education."

It should also be pointed out that the present study is concerned with only the libraries at the University of Michigan. Before the results can be generalized, the findings concerning cataloging costs, characteristics of card catalog use, and possible benefits from remote access to central catalogs should be studied and verified at libraries elsewhere.

In addition, alternative library uses of the equipment should be investigated before a decision is made as to the usefulness of this equipment to libraries in general. The portion of cataloging costs associated with the maintenance of divisional library catalogs constituted only about 2.5% of the total costs associated with maintaining the Catalog Department of the University Library system. Perhaps some larger area of cataloging costs in this and other university libraries may be amenable to reduction through use of Telereference or other equipment. For instance, such equipment may facilitate the actual cataloging operations by providing remote access (even within one building) to one large central catalog for the benefit of Catalog and Order Department staff who must consult catalogs frequently in the course of their work. Also, the value of Telereference access to the central Public Catalog from remote locations, such as the North Campus at the University of Michigan, or the Flint Branch, may be great enough to justify the cost of the few Telereference units needed.

It also appears reasonable that combining (into one central, mechanized catalog) all or parts of several University or city library catalogs within a certain geographical region may produce cost savings more nearly proportionate to the cost of the mechanizing and remoting equipment required than was found in the present case.

The amount of equipment needed for the operation of any system utilizing a central catalog with remote access will depend greatly on the length of time required to locate information. The findings of the present study suggest that the distribution of holding times may be more strongly dependent on the structure of information in the catalog than on other factors associated with catalog use. If this is indeed true, information conceivably might be structured in catalogs to result in other than lognormal distributions of holding times. It thus appears that further research into this aspect of the cataloging operation may be a vital prerequisite in the ability to design efficient mechanized card catalog systems.

THE UNIVERSITY OF MICHIGAN LIBRARIES AND CARD CATALOGS

1. DESCRIPTION OF THE LIBRARIES

The University Library system of the University of Michigan includes administratively the General Library, the Undergraduate Library, the North Campus storage annex, as well as numerous "divisional" libraries and special departments. It does not include the Law Library, the Clements Library (rare Americana), the Business Administration Library, the Michigan Historical Collections, the Flint Campus Library, the (projected) Dearborn Campus Library, or the research library located at the Willow Run Laboratories, all of which are administratively autonomous.

The Business Administration Library has divisional library status in the University Library system insofar as acquisitions, cataloging records, and procedures are concerned. The Law Library, the Clements Library, and the Michigan Historical Collections cooperate with the branches and divisions of the University Library, so that all University library resources are accessible.

The Divisional Libraries are located in academic buildings on the Ann Arbor campus. These libraries are intended to support the teaching and research programs of the faculty departments housed in or near those particular buildings. Thus, the University Library system is spread over quite a wide geographic area, especially when it is noted that one divisional library is located on the North Campus (in addition to the Storage Annex), while two of the special University Library branches are located as far away as Detroit and Grand Rapids.

The newly-completed Undergraduate Library Building includes three floors of Undergraduate Library activities and book collections, as well as three subject divisional libraries: Education, Engineering, and Transportation.

The General Library Building houses the bulk of the University Library's book stock, as well as the following Public Service Departments and units. Descriptions of the catalogs and several check lists mentioned are given in Section 3 below.

Reference Department

Located in the Main Reading Room, this unit provides general information service and research assistance. It also cares for the general reference book collection, operates the separate Map Room, and carries on the Inter-Loan program. This department has a separate card catalog of its reference holdings but relies heavily on the Public Catalog.

Circulation Department

This department operates the central book stacks, the general Loan Desk,

and the Periodical Reading Room (current issues). It also is responsible for management of the North Campus storage annex, which is housed in a specially-designed stack structure 2.3 miles from the General Library Building. This department relies heavily on the Public Catalog and on the Union Shelf List.

Graduate Reading Rooms

These are three small divisional libraries devoted to the humanities and the social sciences, which have card catalogs of their own holdings.

Far Eastern Library

This is a large divisional-type library containing only oriental material. It has a unique card catalog written in Far Eastern characters. This catalog is not duplicated elsewhere in the University Library.

Rare Book Room

This is the University Library's "treasure room," and it too has a card catalog of its own holdings.

Library Extension Service

This unit provides mail service to schools, etc., throughout the state, serves U. of M. students off-campus, and assists other individuals without local library service. This unit has several small collections which are fully cataloged.

The General Library Building also houses the following Administrative and Technical Departments and units:

Director's Office

This headquarters of the University Library system includes quarters for the Director, the Associate Director (Public Service Departments), the Assistant Director (Technical Service Departments) two Assistants to the Director, and secretarial assistants.

Book Selection Department

This unit coordinates the choice of publications for acquisition, transfer, and withdrawal, and makes extensive use of the Public and Official Catalogs as well as the Serials Checklists.

Order Department

This department purchases books, serials, and government publications; handles binding and rebinding; and processes orders for general equipment and supplies. Its staff uses the Official Catalog, Depository Union Catalog, and the Serials Checklists.

Exchange and Gift Department

This unit negotiates agreements for institutional exchange of publications, and processes publications received as gifts. This department uses the Official Catalog and Serials Checklists.

Catalog Department

This department performs bibliographical description, classification, and subject cataloging for all University Library books and serials; prepares catalog and shelf list cards for all University card catalogs; and maintains several of the card catalogs located in the General Library Building. This group uses extensively the Official Catalog, Depository-Union Catalog, and the Serials Checklists.

Photoduplication Service

This unit performs general photostat, microfilm, xerographing, and multilithing service. It also reproduces catalog cards from copy prepared by the Catalog Department.

2. HOLDINGS OF THE LIBRARIES

The holdings of the University Library system, plus other U. of M. libraries (44 in all), now exceed $2\frac{1}{2}$ million volumes. The chief library units with separate book collections, and the number of volumes in each (exclusive of microfilm publications) as of July 1, 1957 were:

("D" denotes divisional libraries; "B" branch libraries; "S" special departments; and "A" autonomous libraries, not part of the University Library system).

(1)	D Architecture	15,216
(2)	D Astronomy	15,740
(3)	B Biological Station	5,709
(4)	D Bureau of Government	39,532
(5)	A Business Administration	113,175
(6)	D Chemistry	23,421
(7)	A Clements Library	36,333
(8)	D Dentistry	17,742
(9)	B Detroit Branch	8,032

The University of Michigan • Engineering Research Institute

(10)	D Education	24,596
(11)	D Engineering	126,807
(12)	B Extension	6,287
(13)	D Fine Arts	12,000
(14)	A Flint Branch	8,007
(15)	General Library	1,281,847
(16)	B Journalism	308
(17)	D Lane Hall	1,702
(18)	A Law Library	276,468
(19)	S Library Extension	6,173
(20)	D Library Science	9,537
(21)	D Mathematics-Economics	28,639
(22)	B McMath-Hulbert	2,011
(23)	D Medical	117,631
(24)	B Mental Health	1,006
(25)	D Museums	51,620
(26)	D Music	11,068
(27)	D Natural Science	81,977
(28)	D Nursing	2,544
(29)	D Phoenix	1,713
(30)	D Physics	18,322
(31)	D Public Health	10,689
(32)	D Social Science	10,260
(33)	B Statistical Research	340
(34)	D Transportation	117,913
(35)	S Undergraduate Library	30,910
	Total	<u>2,515,275</u>

The count shown for the General Library includes volumes belonging to the following:

(36)	S Circulation (General Stacks)
(37)	B North Campus Annex
(38)	S Reference Department
(39)	S Rare Book Room
(40-42)	D Graduate Reading Rooms (3)
(43)	D Far Eastern
(44)	B Grand Rapids Branch

No count is available of the volumes contained in the Michigan Historical Collections. As of May 1, 1958, the Undergraduate Library contained approximately 62,000 volumes. There are almost 4,000 books at the Willow Run research library.

3. CARD CATALOGS ASSOCIATED WITH THE LIBRARIES

The following card catalogs are maintained to make the above 2½ million volumes accessible:

Public Catalog

Located in the second floor hall of the General Library Building, between the Reference Department and the Circulation Department, this catalog is intended for the use of all students, faculty members, research workers, and visiting scholars. It contains author, title, added entry series, subject, and cross-reference cards for all books in the University Library system, as well as main entry cards for books belonging to the Law Library, the Clements Library, and the Michigan Historical Collections. It contains 3,125,300 cards housed in some 3,768 drawers.

Departmental and Divisional Catalogs

Almost all the special branches and divisional libraries maintain catalogs listing all the books available in their own quarters. Such catalogs contain author, added entry, title, and subject cards. Since their books also appear in the Public Catalog in the General Library Building, departmental and divisional books are "listed twice" for the convenience of library patrons. The Undergraduate Library is unusual in that it has not only a general catalog for its collection, but separate floor catalogs for the holdings on each of its three floors.

Law, Clements, Michigan Historical, Etc.

These libraries maintain separate catalogs, and carry on completely autonomous procurement and cataloging operations.

In addition to the card catalogs maintained for all members of the University community, several additional catalogs are maintained principally for members of the University Library staff, especially the Order Department and the Catalog Department.

Official Catalog

Located in the work room of the Catalog Department, this file contains author, added entry, name cross-reference, and selected title cards (but relatively few subject cards) for all books in the University Library system, as well as main entry cards for Law, Clements, and Michigan Historical. This catalog significantly reduces staff use of the Public Catalog and facilitates many cataloging operations, but entails additional maintenance expense.

Depository-Union Catalog

This catalog is also housed in the Catalog Department work room. It contains cards for all books acquired and cataloged at the Library of Congress since 1942, and from a group of other university libraries, most notably the University of Illinois Library. It provides assistance in the bibliographical description, subject cataloging, and photoduplication of

cards for many books acquired by the University of Michigan.

Shelf Lists

All library units with card catalogs, as well as the central catalog Department, maintain shelf lists. These files are catalogs consisting of one card per title arranged by the classification numbers ("call numbers") assigned to the publications they represent. The large "Union" Shelf List maintained in the Catalog Department is a tool essential to the classification process, while the much smaller departmental and divisional library shelf lists make possible inventory of the volumes on the shelves. However, it would be very difficult to inventory the General Library stacks using the Union Shelf List.

Serials Checklists

Since magazines, journals, annual reports, numbered series, etc., are constantly being published, the upkeep of serials records must be continuous. This process would become quite burdensome if "holdings" (i.e., exact detail as to individual volumes and dates) were to be shown in the complex card catalogs. Accordingly, the serial holdings of the University system are not shown in the Public, Official, or Divisional Catalogs. Instead, reference is made from appropriate cards in the Public and Official Catalogs to the serials "Checklist," which is kept up to date as new serials arrive. This file consists of two parts: The Current Checklist maintained in the Order Department, and the Continuations Checklist maintained in the Catalog Department. The former lists all current issues up to three years old, while the latter lists all non-current and bound serial volumes. Although most departmental and divisional libraries maintain duplicate current checklists of their own, none of them keep any records similar to the Continuations Checklist. Instead, their non-current and bound holdings are posted on the local shelf list cards, with references to the card catalogs.

4. CATALOGING PROCEDURES

A general understanding of the cataloging process necessary for each acquisition being cataloged for the first time can be obtained from study of the Flow Chart, Exhibit A-1. Numbers in parenthesis in this section refer to operation numbers used on the Flow Chart. The chart shows the sequence of processes used by the Technical Services Departments of the University Library to produce the cards needed for cataloging the bulk of the acquisitions purchased, donated, and received by exchange. The occasional deviations from the chart usually occur in professional cataloging rather than in production activities, due to the individualized descriptive and subject consideration given each acquisition.

The process of assimilating an acquisition into the Library system starts when a requisition from a staff or faculty member requesting a specific publication is received by the Order Department (1). The Order Department

searches the Current Checklist when appropriate, the Outstanding Order File, and Official Catalog to avoid duplicate purchases; when necessary it also searches the Depository Catalog and various trade bibliographies to check and clarify descriptions and to supply missing information (2). Next, the order fanfold is typed (3) and copies are sent to the supplier, and the publication is subsequently received from the supplier. A gift or exchange is handled by the Gift or Exchange Department rather than the Order Department, but the procedures through the Catalog Department are similar to a purchased acquisition.

The Catalog Department functions fall into five broad activities:

1. Searching
2. Descriptive Cataloging for monographs
3. Descriptive Cataloging for serials and series
4. Subject Cataloging
5. Physical Processing

A monographic acquisition, the original order request, and four copies of the order fanfold are delivered by the Order Department to the searchers in the Catalog Department. The Official and Depository Catalogs are searched and may be found indicating that a copy of the acquisition has previously been cataloged by the University Library system, by the Library of Congress, or by one of the libraries represented in the Depository (6). Any cards found, together with the acquisition, the order request, and fanfold slips, are delivered to the descriptive cataloger for use in preparing descriptive information needed for the card set (7). When no cards are found, an original descriptive card is prepared by the cataloger, usually in rough draft form (14).

A new serial acquisition, the original order request, and four copies of the order fanfold are delivered first to the Serials Catalog Section. After searching the Continuations Checklist, a serials cataloger decides or, in some cases, obtains a decision from the acquiring library unit, whether the acquisition is to be part of an analyzed or unanalyzed set, or to be classed separately as a monograph (26). The acquisition then goes to the searchers as for monographs above (6). The analyzed sets, and separately classed acquisitions are then forwarded to the monographic descriptive cataloger for processing similar to the monographs (7) (14). Next, they are returned to a serials descriptive cataloger for appropriate descriptive cataloging of the series and preparation of holdings cards for the checklists and division shelf lists when needed (21) (22). A temporary slip is also typed, when required, for the Continuations Checklist, and filed by the serials descriptive cataloger (23). The unanalyzed set acquisitions are sent back directly from searching to the serials descriptive cataloger since no monographic descriptive cataloging is needed. In either case, if the searching of the Official and Depository Catalogs and Continuation Checklist has been unfruitful, the monographic and/or serial descriptive cataloger will need to prepare original cards, either in rough draft form or, in some cases, final typed form suitable for reproduction.

After descriptive cataloging, all acquisitions go to subject catalogers

for selection of appropriate subject headings and subject cross references, and for assignment of classification and book numbers (8).

Next, the acquisition goes to the Catalog Department's processing section. Here, the call number is typed on the four copies of the order fanfold, the original order request, and the holdings cards, if any (9). The acquisition is then labeled and forwarded to the acquiring library unit together with two copies of the fanfold for use as temporary catalog slips. The original order request and copies of the fanfold are returned to the Order Department for use in clearing their files (15), and are used as temporary slips in the Official Catalog, Shelf List, and Public Catalogs (24). The current holdings card, if any, is filed in the Order Department Current Checklist. Although not in its permanent form, the cataloging is now sufficiently complete so that the acquisition can be made available to library users. The selection of the process for reproducing multiple copies of the permanent catalog card is based on the form of the cataloging information for the particular acquisition. If Official or Depository Cards have been found in the searching process, or if an original card has been suitably typed, the processing section will prepare instructions to the Photoduplication Service for use in Xeroxing the card (10). If only a rough draft of the original catalog is available, the processing section will type a multilith master (25) which, like the multilith master made from Xeroxing, will be used for production of the required number of catalog cards in the Photoduplication Service. In a few cases, complete sets of cards are acquired from the Library of Congress and no duplication is required. If only one or two cards are needed, typed cards are usually used.

After reproduction, cards are completed by the processing section by stamping appropriate locations and typing order numbers and secondary entries (12). Cards are proofread, assembled into sets, and sent to the acquiring divisional library (16), the subject cataloger for filing in the Union Shelf List (19), the Serial Catalog Section (when pertinent) for filing in the Continuations Checklist (18), and to the Official and Public Catalogs (20) where they are filed directly by the processing section and Public Catalog maintenance section.

APPENDIX B

COST ANALYSIS

1. INTRODUCTION

The replacement of existing divisional card catalogs with visual monitors, connected by closed-circuit television to a central card catalog, will require additional expenditures, initially for the equipment, and annually thereafter for maintenance and upkeep. However, certain expenditures now incurred in connection with the divisional catalogs will be eliminated when the catalogs are replaced. These expenditures occur in two places, (1), the Catalog Department, and (2), the divisional libraries. In calculating the cost saving, the following were determined:

1. The procedures now in effect that would be eliminated or modified by the installation of the television system.
2. The time spent in these procedures and operations.
3. The labor cost applicable to this time both with and without direct labor overhead, the calculation of which is shown on Exhibit A-1.
4. The material saved.

The above method of estimation was adopted even though it was realized that little, if any, of the labor "saved" would be saved by the actual elimination of personnel, rather, personnel would be released for reassignment or redirection of effort. Nonetheless, this measure was deemed appropriate. It should be emphasized, therefore, that many indirect costs of the Catalog Department are not included. For example, the cost of supervision is not included, nor is the cost of training and instruction. The cost of training part-time typists in the processing group in particular, is believed to be considerable because of high turnover. No allowance for non-productive periods, usually considered a normal part of the working day, was included in the labor time. Furthermore, some extra cataloging skill and time now required by the special subject requirements for some of the divisional libraries could be eliminated. The use of television monitors might lead to standardization of subject headings and hence affect the amount of assistance and training that the Reference and Cataloging Departments render the divisional librarians. Little if any change or savings were foreseen in the ordering procedures, descriptive and subject cataloging, labeling and book handling, fanfold typing and filing in Central and Official catalogs.

Approximately \$7,000 per year would be saved if the divisional shelf lists were retained and the divisional catalogs eliminated. If, however, both the divisional catalogs and the divisional shelf lists were eliminated, the savings would be increased to approximately \$10,000 per year. These costs savings are shown in Table I, Section 2 of the main body of the report and their development explained below, and represent the combined savings possible at all "Divisional," "Branch," and "Autonomous" Libraries and

"special departments" listed in Appendix A with the exception of the Clements Library, the Flint Branch, the Law Library, and of course the General Library.

No attempt was made to estimate the cost effects of utilizing closed-circuit television in the Order Department, the Reference and Research Department or in the Catalog Department itself. Although such an examination would be informative it was beyond the scope of the present study.

2. DEFINITIONS AND SCOPE OF STUDY

The cataloging system of the University of Michigan at present includes a Central Public Catalog, a central or Union shelf list, an Official catalog (a main and added entry catalog of all books in the system), divisional catalogs, and divisional shelf lists as described in Appendix A. For this study, the Central Card Catalog was deemed complete, and no consideration was given to any costs involved in adapting its contents for television use.

Acquisitions must be cataloged whether or not the divisional library catalogs exist. Of concern were operations that would be modified or eliminated by the introduction of closed-circuit television as a replacement for divisional catalogs. With the exception of catalog revisions, corrections, and transfers, the only operations in the cataloging process, which would be modified or eliminated, occur after the descriptive and the subject cataloging have been completed. Effectively, then, these operations occur in the process of production and reproduction of the additional cards required for the divisional library "sets." A set of cards is here understood to mean the cards which are placed in the card catalog used by the public; it does not include the shelf list or inventory card. This set includes an author or main entry card, and may include a title card, subject cards, cross reference cards, added entry cards, etc. It is assumed that, for a divisional library, a set consists on the average of four and one half cards.

The number of cards prepared for an acquisition depends on the particular title as well as on whether the title is new to the library system, new to the particular library, or merely an additional copy in the same library. Technically, acquisitions are classed as New Titles, Other Copies, and Added Volumes or Added Copies, with the requirements for their catalog sets as follows:

New Titles

New Titles requires a catalog set for the Central Public Catalog, a Union shelf list card, a card for the Official catalog plus a set and a shelf list card for the divisional library if that is its destination.

Other Copies

Other Copies are titles already cataloged in the library system but new to the particular library receiving them. In this case, a catalog set and a shelf list card for the acquiring library are required but none are needed

for the Official or the Central Public catalog.

Added Copies and Volumes

Added Copies and Added Volumes are duplications of titles in the acquiring library or an addition to a series already cataloged in the acquiring library. These require no additional catalog cards but merely require notation on some of the cards already in the catalog or shelf list.

Transfers of books between libraries will be considered with card corrections in Section 4.

Reproduction of the catalog cards is accomplished in one of the following ways:

1. A Library of Congress card (obtained on subscription) or comparable catalog card with additional notation is Xeroxed. Xeroxing is a method of positive facsimile reproduction resulting in a multilith master for production of multiple copies. The individual cards next have specific information typed or hand stamped on each, depending on whether they are to be used as shelf list, cross reference, or main entry cards.
2. In some cases, the original cataloger's guide is copied by typing directly on a multilith master and completed as above.
3. Finally, some are prepared directly by typing.

In the analysis methods (1) and (2) above were considered together. Method (3), that of direct typing, is involved only rarely with the divisional sets and is not considered. The cost savings depend on the procedures involved which vary with the class of acquisition, i.e., New Title, Other Copy, Added Copy or Added Volume. Consequently, the analysis is divided into these categories.

The information used in the calculations was obtained from "The University of Michigan Library Acquisition Summary for 1956-57," and a "Statistical Supplement of the Catalog Department" for the same period. This period is taken to be representative and, with revisions described, has been used as a basis of cataloging activities. The statistics taken from the Acquisitions Summary have been revised to account for the effect of the Undergraduate Library acquisitions when its estimated size of 75,000 volumes is reached. The division library acquisitions, excluding those of the Undergraduate Library, were at the rate of 3.2% of their holdings during the 1956-57 University year. Therefore, the "normal number" of acquisitions for the Undergraduate Library is calculated to be 3.2% of 75,000 volumes or 2,400 volumes. The revised total of division library acquisitions for a representative year is shown in Exhibit B. In addition to the quantitative information cited above, personal interviews with the divisional librarians and members of the Catalog Department were utilized to obtain estimates of certain activities' costs. A questionnaire was sent to the divisional librarians requesting information as to number of cards in the catalogs, time spent in catalog maintenance, and job classifications of divisional library personnel.

Finally, work measurements and direct observations were made of operations such as filing of cards, pulling of cards, and other processing procedures.

3. CALCULATIONS OF INITIAL CATALOG AND PHOTO-REPRODUCTION DEPARTMENT COSTS SAVINGS

Library shelf lists are inventory records of the library holdings filed by call or classification number. At present, both a Union Shelf List, complete for the whole University, and divisional shelf lists are maintained. When eliminating the divisional card catalog, it would be possible either to retain the divisional shelf lists or to eliminate the divisional shelf lists and use only the existing Union Shelf List. Since either alternative may be feasible, calculations of the cost savings are made for both.

New Titles

During the representative year 1956-57, an adjusted total of 22,800 New Titles and New Editions were cataloged. Some of these were acquired by the divisional libraries and the remainder by the General Library. The number of New Titles going to divisional libraries was estimated to be 10,300 titles, the remaining 12,500 going to the General Library, (see Exhibit C). New Titles going to the General Library are not considered in this cost analysis since the cataloging process would remain unchanged. New Titles going to the divisions require preparation of a Central Public Catalog set, a Union Shelf List card, and a card for the Official catalog; this requirement would be unchanged. However, the cards for the divisional set would not be needed and the following cataloging procedures would be eliminated:

1. Xeroxing of the additional catalog set in the Photoduplication Department.
2. Typing subject headings, joint authors, etc., and stamping the appropriate catalog location on each divisional card by the Processing group.
3. Proofreading each card by the Processing group for errors in typing or stamping.

Preparation of a divisional shelf list card, if necessary, would involve merely time and material in multilithing and checking an additional card. Costs both with and without the divisional shelf list, are as follows:

1. To Xerox the divisional catalog set

a. With retention of divisional shelf lists:

$$(titles) (cards/title) (min/card) (rate/min)$$

$$(10,300) \times (4\frac{1}{2}) \times (.015) \times (\frac{\$1.92}{60}) = \$ 22.00$$

b. Without retention of divisional shelf lists:

$$(title) (cards/title) (min/card) (rate/min)$$

$$(10,300) \times (5\frac{1}{2}) \times (.015) \times (\frac{\$1.92}{60}) = \$ 27.00$$

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2. Typing and stamping

a. With retention of divisional shelf lists:

$$(titles) (cards/title) (min/card) (rate/min) \\ (10,300) \times (4\frac{1}{2}) \times (1) \times (\frac{\$1.20}{60}) = \$ 927.00$$

b. Without retention of divisional shelf lists:

$$(titles) (cards/title) (min/card) (rate/min) \\ (10,300) \times (5\frac{1}{2}) \times (1) \times (\frac{\$1.20}{60}) = \$1,133.00$$

3. Proofreading

a. With retention of divisional shelf lists:

$$(titles) (cards/title) (min/card) (rate/min) \\ (10,300) \times (4\frac{1}{2}) \times (\frac{1}{3}) \times (\frac{\$3.46}{60}) = 891.00$$

b. Without retention of divisional shelf lists:

$$(titles) (cards/title) (min/card) (rate/min) \\ (10,300) \times (5\frac{1}{2}) \times (\frac{1}{3}) \times (\frac{\$3.46}{60}) = 1,090.00$$

4. Direct material

a. With retention of divisional shelf lists:

$$(titles/year) (cards/title) (cost/card) \\ (10,300) \times (4\frac{1}{2}) \times (\frac{\$15.50}{4000}) = 179.00$$

b. Without retention of Divisional shelf lists:

$$(titles/year) (cards/title) (cost/card) \\ (10,300) \times (5\frac{1}{2}) \times (\frac{\$15.50}{4000}) = \underline{219.00}$$

TOTAL \$1,997.00 \$2,442.00

Other Copies

A total of 4,200 Other Copies were cataloged during the 1956-57 year (as adjusted). Of these, it is estimated that 2,000 were acquired by the divisional libraries. (Exhibit C). Since an Other Copy would have already been cataloged for some University Library other than the acquiring library, the Official and Central Public Catalog cards would previously have been prepared. However, a shelf list card, divisional catalog set, and Union shelf list card would be required if the copy goes to a divisional library. Note that if all divisional library cards were eliminated, the Union shelf list card would still be needed. At present the divisional catalog cards are prepared by Xeroxing or multilith. If only the shelf list cards were retained, it would no longer be economical to prepare them by the Xerox process. It is thus assumed in the following cost analysis that if only a Union shelf list card

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is prepared, it would not be Xeroxed but typed directly by the Processing group. It is likewise assumed that if a division shelf list card were required it would also be typed. Based on these assumptions, the following operations would be eliminated:

1. Preparation of a card by the Processing group in the Catalog Department with instructions for the Photoduplication Department concerning the details and number of cards to be included in each set.
2. Xeroxing of the division card set plus the division shelf list and Union shelf cards by the Photoduplication Department.
3. Typing of subject headings, joint authors, etc., and the stamping of the appropriate catalog location on each division card in the Processing group.
4. The proofreading of each card in the Processing group for errors in typing or stamping.

The estimated Cost Saving by operation is shown below:

1. Instructions for Xeroxing

$$(2,000) \times \left(\frac{1}{3} \text{ min}\right) \times \left(\frac{\$3.46}{60}\right) = \$ 38.00$$

2. Xeroxing

$$(2,000) \times (1,840 \times 2) \times \left(\frac{1}{96,000}\right) \times (\$1.92) = 147.00$$

3. Typing and stamping each card

$$(2,000) \times \left(6\frac{1}{2}\right) \times (1 \text{ min}) \times \left(\frac{\$1.20}{60}\right) = 260.00$$

4. Proofreading each card

$$(2,000) \times \left(6\frac{1}{2}\right) \times \left(\frac{1}{3}\right) \times \left(\frac{\$3.46}{60}\right) = 250.00$$

5. Material cost

$$(2,000) \times \left(6\frac{1}{2}\right) \times \left(\frac{\$15.50}{4000}\right) +$$

$$(2,000) \times \left(\frac{1}{8}\right) \times (\$.10) = \underline{75.00}$$

Total Cost Savings \$770.00

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The elimination of Xeroxing the cards necessitates the preparation of a Union shelf list and a divisional shelf list card if the divisional shelf list is retained. These cards must be typed and the estimated cost addition is shown below:

1. Type shelf list cards

a. With retention of division shelf lists:

$$(2,000) \quad x \quad (2) \quad x \quad (1\frac{1}{2}) \quad x \quad (\frac{\$1.20}{60}) = \$120.00$$

b. Without retention of division shelf lists:

$$(2,000) \quad x \quad (1) \quad x \quad (1\frac{1}{2}) \quad x \quad (\frac{\$1.20}{60}) = \quad \$ 60.00$$

2. Proof reading shelf list card

a. With retention of division shelf lists:

$$(2,000) \quad x \quad (2) \quad x \quad (1 \text{ min}) \quad x \quad (\frac{\$3.46}{60}) = 230.00$$

b. Without retention of division shelf lists:

$$(2,000) \quad x \quad (1) \quad x \quad (1 \text{ min}) \quad x \quad (\frac{\$3.46}{60}) = \quad 115.00$$

3. Additional material

a. With retention of division shelf lists:

$$(2,000) \quad x \quad (2) \quad x \quad (\frac{\$15.50}{4000}) = \quad 16.00$$

b. Without retention of division shelf lists:

$$(2,000) \quad x \quad (1) \quad x \quad (\frac{\$15.50}{4000}) = \quad \underline{\quad\quad\quad} \quad \underline{8.00}$$

$$\text{Total Cost Additions} \quad \underline{\underline{\$366.00}} \quad \underline{\underline{\$183.00}}$$

Added Copies and Added Volumes

A total of 35,000 Added Copies and Added Volumes were acquired during 1956-57 (Exhibit B). These acquisitions have already been cataloged both in the Central Catalog and at the divisional library where the book will be shelved. Therefore, no additional cataloging is required for an Added Copy or Added Volume, and thus no Catalog Department costs would be eliminated or changed if Divisional catalogs were supplanted by television.

4. CARD CORRECTIONS AND TRANSFERS

A second potential cost savings arises in connection with transfers and corrections of divisional catalog cards. Such corrections are needed if an organization publishing a title changes its name, if the Library of Congress changes its subject classification, if the book is transferred from one library to another, or if errors are discovered. In these instances, almost all the cards to be changed are sent to the Catalog Department, corrected, and returned. In a minority of cases, the cards, are corrected in the divisional library. Since the cards in the Central Catalog must be corrected even if divisional libraries have no catalogs, only the steps directly associated with divisional library cards are pertinent, as follows:

1. A descriptive and/or subject catalog clerk in the Catalog Department orders from the division, receives, examines, and checks each set to be corrected or changed.
2. The Processing group erases and types in the new headings or the corrections.
3. The corrected cards are proofread and returned to the divisional library.

In 1956-57, 10,000 divisional catalog cards were corrected. This is taken to be representative for one year's operations. Not included in the 10,000 divisional cards corrected are the cards pertaining to some 400 transfers from divisional libraries to the General Library. These cards are pulled and destroyed. In addition, some 2,000 volumes (estimated from the 1956-57 Acquisition Summary) are transferred from the General to a divisional library. Approximately one-half of these Transfers are assumed to be Additional Copies or Volumes to divisional libraries, and hence require no additional catalog cards. The remainder, however, require preparation of a complete catalog set plus a shelf list.

Activity

Divisional cards corrected in a year	10,000 cards
Inter-divisional Transfers included in above figure	100 sets
Transfers from Divisional to General	400 sets
Transfer from General to Divisional	2,000 sets
Average size of sets corrected $4\frac{1}{4}$ cards + shelf list	$5\frac{1}{2}$ cards
Cards corrected not due to Transfers $10,000 - (100 \times 5\frac{1}{2})$	9,450 cards
The number of sets represented by these 9,450 cards is estimated to be approxi- mately	2,100 sets

Card Correction Cost Savings

1. With retention of divisional shelf lists:

a. Obtain cards to be corrected

Most corrections involve the catalog set only, since the shelf list cards need to be corrected only in approximately 10% of the cases. Since the number of divisional sets corrected is 2,100, shelf list cards will be needed in 210 cases. Thus, the number of divisional sets (eliminated by television) now requiring corrections will be 2,100 - 210 or 1,890.

$$\begin{array}{r} \text{(number of sets)} \quad \text{(min/set)} \quad \text{(rate/min)} \\ (1,890) \quad \times \quad (5) \quad \times \quad (\$1.78/60) = \end{array} \quad \$280.00$$

b. Erase and type new headings etc.

$$\begin{array}{r} \text{(number of cards)} \quad \text{(min/card)} \quad \text{(rate/min)} \\ (10,000 - 310) \quad \times \quad (2) \quad \times \quad (\$1.20/60) = \end{array} \quad 387.00$$

c. Proofread

$$\begin{array}{r} \text{(number of cards)} \quad \text{(min/card)} \quad \text{(rate/min)} \\ (10,000 - 310) \quad \times \quad \left(\frac{1}{3}\right) \quad \times \quad \left(\frac{\$3.46}{60}\right) = \end{array} \quad \underline{186.00}$$

$$\text{Total Card Correction Savings} \quad \underline{\underline{\$853.00}}$$

2. Without retention of divisional shelf lists:

a. Obtain cards to be corrected

Transfers (inter-divisional)	100 divisional sets
Corrections	2,100 divisional sets
Total	2,200 divisional sets

$$\begin{array}{r} \text{(number of sets)} \quad \text{(min/set)} \quad \text{(rate/min)} \\ (2,200) \quad \times \quad (5) \quad \times \quad (\$1.78/60) = \end{array} \quad \$326.00$$

b. Erase and type

$$\begin{array}{r} \text{(number of cards)} \quad \text{(min/card)} \quad \text{(rate/min)} \\ (10,000) \quad \times \quad (2) \quad \times \quad (\$1.20/60) = \end{array} \quad 400.00$$

c. Proofreading

$$\begin{array}{r} \text{(number of cards)} \quad \text{(min/card)} \quad \text{(rate/min)} \\ (10,000) \quad \times \quad \left(\frac{1}{3}\right) \quad \times \quad (\$3.46/60) = \end{array} \quad \underline{192.00}$$

$$\text{Total Card Correction Savings} \quad \underline{\underline{\$918.00}}$$

Transfer Cost Savings

The costs involved are those for the preparation of 1,000 sets of catalog cards. The catalog procedures are identical with those for Other Copies shown on pages 39 through 43. One exception is that a Union Shelf List has already been prepared, hence the cost additions would be those of typing one shelf list card if the divisional shelf list were eliminated.

Since the volume for transfers is one-half that shown for other copies, the cost savings would be $\frac{1}{2}$ of \$770 or \$385. The cost addition with retention of divisional shelf lists would be $\frac{1}{2}$ of \$182 or \$91 and nonexistent if the divisional shelf lists were eliminated.

Summary of Transfer Cost Savings

1. With retention of divisional shelf lists	
Cost Savings	\$385.00
Cost Additions	<u>91.00</u>
Total Savings	<u><u>\$294.00</u></u>
2. Without retention of divisional shelf lists	
Cost Savings	\$385.00
Cost Additions	<u>- 0 -</u>
Total Savings	<u><u>\$385.00</u></u>

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SUMMARY OF CENTRAL CATALOGING COST SAVINGS

	With Retention of Shelf List		Without Retention of Shelf List	
	Labor & Materials	Labor Overhead	Labor & Materials	Labor Overhead
I. INITIAL CATALOGING				
A. New Titles				
1. Xeroxing	\$ 22	\$ 3	\$ 27	\$ 4
2. Typing & Stamping	927	21	1,133	26
3. Proofreading	891	137	1,090	168
4. Materials	179		219	
Total	(A) <u>\$2,019</u>	<u>\$161</u>	<u>\$2,469</u>	<u>\$198</u>
B. Other Copies				
1. Cost Savings				
a. Instructions for				
Xeroxing	\$ 38	\$ 6	\$ 38	\$ 6
b. Xeroxing	147	20	147	20
c. Typing & Stamping	260	6	260	6
d. Proofreading	250	38	250	38
e. Materials	75		75	
Subtotal Savings	<u>\$ 770</u>	<u>\$ 70</u>	<u>\$ 770</u>	<u>\$ 70</u>
2. Cost Additions				
a. Typing	\$ 120	\$ 2	\$ 60	\$ 1
b. Proofreading	230	36	115	18
c. Materials	16		8	
Subtotal Costs	<u>366</u>	<u>38</u>	<u>183</u>	<u>19</u>
Total	(B) <u>\$ 404</u>	<u>\$ 32</u>	<u>\$ 587</u>	<u>\$ 51</u>
C. Added Copies & Added Volumes	(C) <u>-0-</u>	<u>-0-</u>	<u>-0-</u>	<u>-0-</u>
Total - Initial Cataloging Cost Savings (Lines A + B + C)	I <u>\$2,423</u>	<u>\$193</u>	<u>\$3,056</u>	<u>\$249</u>
II. CARD CORRECTION AND TRANSFERS				
A. Card Corrections				
1. Obtain Cards	\$ 280	\$ 33	\$ 326	\$ 40
2. Erase and Type	387	9	400	9
3. Proofread	186	29	192	30
Total	(A) <u>\$ 853</u>	<u>\$ 71</u>	<u>\$ 918</u>	<u>\$ 70</u>
B. Transfers				
1. Cost Savings	\$ 385	\$ 35	\$ 385	\$ 35
2. Cost Additions	91	10	-0-	-0-
Total	(B) <u>\$ 294</u>	<u>\$ 25</u>	<u>\$ 385</u>	<u>\$ 35</u>
Total - Transfers & Corrections (Lines A + B)	II <u>\$1,147</u>	<u>\$ 96</u>	<u>\$1,303</u>	<u>\$114</u>
TOTAL COST SAVINGS IN CATALOG DEPARTMENT (Lines I + II)	<u>\$3,570</u>	<u>\$289</u>	<u>\$4,359</u>	<u>\$363</u>

5. DIVISIONAL LIBRARY COST SAVINGS

Each divisional library is responsible for its own catalog and shelf list. This responsibility falls into three general activities:

1. On receipt of catalog cards from the Catalog Department, the divisional library must file these cards in the proper catalog tray. Often the cards arrive in batches, in which case the cards are
 - a. Alphabetized
 - b. Filed temporarily "above the rod".
 - c. Checked and "rodded" by the Senior Librarian.
2. Pulling or removing cards from the divisional public catalog and shelf list is required if a book is withdrawn by transfer, or if the cards are needed for correction by the Catalog Department.
3. When Added Copies or Volumes are acquired, the shelf list must be amended by the divisional librarian to show the new acquisitions. This cost would be eliminated only if the division shelf list were discontinued.
4. Maintenance of the catalog itself consists of replacing defaced or torn cards, rearranging contents, replacing tray tags, revising index cards, etc. This activity is such a minor part of the librarian's time that it is not considered as a cost in the subsequent analysis.

Activity and procedures among libraries vary. However, after discussion with librarians, and after several test runs of both the filing and pulling operations, the following times and personnel assignments were adopted:

1. Filing per 100 cards
 - a. Alphabetizing by part time help - 15 minutes
 - b. Filing above the rod by a Junior Librarian - 45 minutes
 - c. Checking and rodding by a Senior Librarian - 12 minutes
2. Pulling: $1\frac{1}{4}$ minutes per card performed by a Junior Librarian.
3. Notating the shelf list card: The times for filing and pulling of cards in the shelf list for New Titles and Other Copies are included in 1 and 2 above. Since new shelf list cards are not prepared for Added Volumes or Added Copies, notation of the acquisition must be made on the shelf list card by the divisional librarians. We have adopted a time standard of 1.75 minutes for notating Added Volumes, and 2.25 minutes for the Added Copies.

For determining the cost savings, the adjusted volume of acquisitions for 1956-57 is again used. As shown in Exhibit C, 12,300 New Titles and Other Copies were acquired by the divisions; and the same number of card sets and shelf list cards were filed by the division. The number of cards pulled by the divisional libraries is shown below:

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<u>Activity</u>	<u>Number of Cards</u>
A. With retention of divisional shelf lists:	
New Titles and Other Copies (12,300 x 4½)	55,350
Transfers from General ($\frac{2000}{2}$ x 4½) =	4,500
Transfers from Divisions (100 x 4½) =	450
Cards corrected (9,450 - 310) =	<u>9,140</u>
Total	<u><u>69,540</u></u>
B. Without retention of divisional shelf lists:	
New Titles and Other Copies (12,300 x 5½) =	67,650
Transfers from General ($\frac{2000}{2}$ x 5½) =	5,500
Transfers from Divisions (100 x 5½) =	550
Cards corrected	<u>9,450</u>
Total	<u><u>83,150</u></u>

As 1,350 Added Copies and 14,450 Added Volumes were acquired by purchase and 1,000 by transfers, a like number of shelf list cards were amended by the divisional librarians. The cost saving calculations follow:

1. Filing

a. With retention of division shelf lists:	
(number of cards) (cost per card)*	
(69,540) x (\$3.09/100)	\$2,149.00
b. Without retention of division shelf lists:	
(number of cards) (cost per card)	
(83,150) x (\$3.09/100) =	2,569.00

2. Pulling

a. With retention of divisional shelf lists:	
(number of cards pulled per year) (min/card) (rate/min)	
(10,000 - 100 - 400) x (1.25) x (\$2.80/60) =	554.00
b. Without retention of divisional shelf lists:	
(10,000) x (1.25) x (\$2.80/60) =	584.00

* Determined by applying appropriate rates from Exhibit A to the times required shown on page 46.

3. Notating

a. With retention of divisional shelf lists:

No savings

b. Without retention of divisional shelf lists:

i) (Added Volumes/per year) (min/notation) (rate/min)
 $(14,450 + 1,000) \times (1.75) \times (\$2.80/60) = \$1,262.00$

ii) (Added Copies/year) (min/notation) (rate/min)
 $(1,350) \times (2.25) \times (\$2.80/60) = \underline{142.00}$

Total (3b) \$1,404.00

SUMMARY OF DIVISIONAL CATALOG
 COST SAVINGS

Operations	With Retention of Divisional Shelf Lists		Without Retention of Divisional Shelf Lists	
	Labor	Labor Overhead	Labor	Labor Overhead
1. Filing	\$2,149	\$285	\$2,569	\$340
2. Pulling	554	77	584	81
3. Notating	-0-	-0-	1,404	195
	<u>\$2,703</u>	<u>\$362</u>	<u>\$4,557</u>	<u>\$616</u>

EXHIBIT B-1

COMPUTATION OF DIRECT LABOR
RATES AND DIRECT OVERHEAD

The determination of the appropriate labor costs was done as follows:

1. For each function in the various locations (divisional libraries or Catalog Department), the type and/or salary classification of the personnel performing the function was determined or estimated. This was done through
 - a. Observation and identification of personnel.
 - b. Discussion with personnel in Catalog Department and with a number of the divisional librarians.

These times and measures of activity are representative only of what is actually being done, and no effort was made to determine whether or not they could be considered "optimal" standards.

2. The pay classifications, rates, hours, supplemental benefits, and direct payroll costs were obtained from the University.
3. Of the several pay classifications, five were selected as representative for the personnel performing the functions under consideration.
4. After discussion with the Library Personnel Officer, a salary of one-third the range between the minimum and maximum starting rates was used to represent that of personnel performing the functions under study.
5. The annual rate obtained above was divided by the number of hours annually worked (1,744 for professional and 1,840 for clerical) to arrive at an hourly rate.
6. Part-time student help are paid \$1.20 per hour, and hence are not involved in (4) above.
7. Age, salary and occupation were taken into account in determining retirement, Social Security, group insurance, and workmen's compensation costs.
8. The resulting hourly rates before and after "direct payroll overhead" costs are shown below.

CALCULATION OF HOURLY RATE WITH OVERHEAD

Overhead Factors in %	Classification of Employees				
	Part-time Student	Clerical		Professional	
		A	B	A	B
Retirement Rate*	- 0 -	6.0	6.5	7.5	7.5
Social Security	2.25	2.25	2.25	2.0	1.56
Group Insurance	- 0 -	3.8	5.1	4.3	6.3
Work Compensation	.06	.06	.06	.06	.06
Total Overhead % (A)	2.31%	12.11%	13.91%	13.86%	15.42%
Annual Salary \$		\$3264	\$3532	\$4884	\$6032
+ Hours Worked Per Year		1840	1840	1744	1744
Hourly Rate (3)	\$1.20	\$1.78	\$1.92	\$2.80	\$3.46
Total Overhead in \$ (A x B)	0.03	0.22	0.27	0.39	0.53
Total Hourly Rate and Overhead	\$1.23	\$2.00	\$2.19	\$3.19	\$3.99

* Age determinate

EXHIBIT B-2

LIBRARY ACQUISITIONS FOR A REPRESENTATIVE YEAR

<u>Class</u>	<u>Without UGL*</u>	<u>UGL*</u>	<u>Total</u>
New Titles	18,800		
New Editions	1,900		
Far East New Titles	1,200		
Total New Titles	21,900	900	22,800
Other Copies	4,200	200	4,400
Total New Titles and Other Copies	26,100	1,100	27,200
Added Copies	2,900	100	3,000
Added Volumes	30,800	1,200	32,000
Total Added Copies and Added Volumes	33,700	1,300	35,000
Total Acquisitions	59,800	2,400	62,200

The above acquisitions were obtained from the Statistical Supplement for 1956-57 of the Catalog Department. The figures are rounded to the nearest 100. The total compares with 57,100 as shown in the Acquisitions Summary for the same period. This difference can be attributed to time lags between purchase or gift and the cataloging process and is not deemed of sufficient importance to warrant further investigation. The Acquisitions shown for the UGL are estimated as 3.2% of their holdings at a capacity of 75,000 volumes.

* Undergraduate Library

EXHIBIT B-3

ESTIMATION OF ACQUISITIONS OF NEW TITLES AND OTHER COPIES
BY DIVISIONAL AND CENTRAL CATALOGS

To determine the destination of New Titles and Other Copies acquired by the University Library system, a sample of 1,400 temporary catalog slips was selected. These catalog slips are main entry cards showing acquiring library, and are prepared in advance of the complete catalog set and filed in the Central Public Catalog. When the permanent cards are ready, the temporary slips are pulled and were available from the 1956-57 University year.

Of the 1,400 slips selected, 589 or 42% were divisional library acquisitions and 811 were those of General Library.

DATA FOR DIVISIONAL ACQUISITIONS
(SEE EXHIBIT B)

New Titles	$(21,900 \times .42) + 900 =$	10,300
Other Copies	$(4,200 \times .42) + 200 =$	2,000
Subtotal	$(26,100 \times .42) + 1,100 =$	<u>12,300</u>
Added Copies	$(2,900 \times .42) + 100 =$	1,350
Added Volumes	$(30,800 \times .42) + 1,200 =$	<u>14,450</u>
Subtotal	$(33,700 \times .42) + 1,300 =$	<u>15,800</u>
Total	$(59,800 \times .42) + 2,400 =$	<u><u>28,100</u></u>

APPENDIX C

SURVEY TECHNIQUES EMPLOYED TO DETERMINE
CHARACTERISTICS OF CARD CATALOG USE

1. GENERAL OBJECTIVES OF THE SURVEY

The plan for collecting data, including the various techniques used, was designed to obtain a maximum of pertinent information consistent with the limited time and financial resources available. The procedure reflects the efforts of the research team to become familiar quickly with the operation of the University of Michigan card catalog system, to select the pertinent information to be obtained or measured, and to select the most economical method of obtaining the information. For these reasons, the test plan was designed in a sequence of steps, so that information obtained in any step was used in the design and conduct of the measurement in succeeding steps.

2. PRELIMINARY INVESTIGATION AND QUESTIONNAIRE USED

The preliminary investigation phase was devoted to visiting various divisional libraries and the Catalog Department, and to becoming familiar with their operating procedures. A literature search was conducted, and pertinent articles and books as shown in the bibliography were studied.

Information obtained in the preliminary investigation was used to design a questionnaire to be sent to all divisional librarians (see Exhibit C-1). This questionnaire was designed to obtain specific information concerning the size and estimated use of each library catalog, which provided estimates of the staff time used in maintaining the card catalog. The questionnaire included general questions concerning various libraries and their card catalogs to provide a better understanding of the operation and mode of use of each of the libraries in the University Library system. Information obtained from the questionnaire was also used to select a sample of 16 divisional libraries for intensive study, including large, "medium," and small catalogs.

3. SPECIFIC INFORMATION NEEDED

The minimum information needed* concerning the characteristics of card catalog use included (1), the distribution of arrival rates to catalogs; (2), the distribution of length of catalog holding time of individual users; (3), the magnitude and duration of peak demands; and (4), the magnitude and duration of the composite system peak demand, consisting of peak demands of all library catalogs combined.

To determine the distribution of arrival rates to the catalogs, it was necessary to record the exact time users arrived at the catalog. To determine

*As discussed in Section 6.

the nature of the distribution of the length of time readers use the catalog, called "holding time," the time had to be recorded when the user first began using the catalog and again recorded when the user finished using the catalog.

4. PRETEST OF DATA COLLECTION FORMS

It was first believed it would be difficult to record the time of arrival and departure of each individual to a catalog, particularly if several people used the catalog at the same time. To determine if this method of recording data was feasible, a data sheet was prepared and the proposed data recording method tested. For the pretests, time of day was chosen when the demands on the catalogs would be heavy. The times chosen were based on estimates obtained from the librarians by means of the questionnaire. The pretest indicated conclusively that the method was feasible for recording data in all libraries, except at the Public Catalog in the General Library. A special procedure then had to be designed for recording data in the Public Catalog, as discussed in Section 6 below.

5. PLAN FOR RECORDING DATA

The plan for recording data was separated into two phases. The first phase was conducted during the week of March 10-14, 1958. The schedule for the first phase (shown in Exhibit C-2) was designed to determine the peak demand on each of the card catalogs studied, and to estimate how the demand varied from day to day during the week. Data concerning the distributions of arrival rates and holding times were obtained as an integral part of this measurement. The schedule shown in Exhibit B was based on the estimated periods of heaviest catalog use obtained from the questionnaire. Data were recorded from 10 a.m. to 8 p.m. (exclusive of the lunch and dinner hours) on the day of the week on which various librarians estimated the greatest demand on each catalog occurred. Data were also recorded every day during the one or two hours during which the librarians estimated the peak demand on the catalog usually occurred. This latter information provided a rough determination of the day and hour when the composite system peak would occur.

Having determined when the system peak would occur, the second phase of data recording was devoted to measuring the magnitude and duration of the system peak. For this purpose, data were taken simultaneously in all libraries studied from 2-5 p.m. on Monday, March 17, 1958. This information was shown previously in Figure 3b in the main body of the report. In addition, data were also recorded on this same day in a few libraries whose peak demand was suspected to occur (based on the previous week's data) at a slightly different hour than the one on which data were recorded the previous weeks.

6. PROCEDURE FOR RECORDING DATA

Two procedures were used in recording data. It was possible to use one procedure in all libraries except at the Public Catalog in the General Library. Due to the heavy demands on the Public Catalog, the large size of this catalog, and the fact that persons continually walk through the Public Catalog area

without using the catalog, a special procedure was needed to record arrival and holding times.

The instructions for recording data at all library catalogs except the Public Catalog in the General Library are shown in Exhibit C-3. The accompanying data sheet used is shown as Exhibit C-4.*

The instruction sheet for recording data at the Public Catalog is shown as Exhibit C-5. Three data sheets were used, including the two sheets shown as Exhibit C-6 and C-7 plus the same data sheet used in other libraries shown previously as Exhibit C-4. A team of 5 or 6 recorders was used at this catalog. Four tasks were designated as described in Exhibit C-5. These tasks were so divided that two persons working together recorded the time of all arrivals to the catalog area, excluding those persons who entered the area but did not use the catalog. The remaining persons were used to record a sample of holding times of users in a manner similar to that used in recording data in other libraries. Of 901 arrivals recorded to the catalog area, a sample of 525 holding times was recorded. The exact procedures used for all tasks are described in Exhibit C-5.

* Note that the time of arrival was defined as the instant a person first touches a drawer. The time of departure was correspondingly defined as the instant a person closes the last drawer used and turns to leave the catalog area. The catalog holding time was thus defined as the difference between time of arrival and time of departure.

EXHIBIT C-1

QUESTIONNAIRE TO LIBRARIANS

1. Name of division library and librarians.
2. Location of division library.
3. How large is your staff?

	full time	part time
Professional		
Clerical		
Students		
Scholars and Fellows		

4. Size of catalog.
 - (a) number of cabinets _____
 - (b) number of trays _____
 - (c) number of cards _____
5. Is the shelf list contained in the same location (cabinet) as the catalog? If not, where is it kept?
6. Do you include serials in your catalog? Are the serial entries in the catalog sufficient or must one look further?

EXHIBIT C-1

7. Do you use other serial records? What?
8. Approximately how many colored cards do you have per tray?
9. Do you have new book lists?
10. How many hours per week do you and your staff use the catalog for filing and maintenance? (Include maintenance for white cards only.)
- minimum _____
- maximum _____
- average _____
11. How many hours per week do you and your staff use the catalog for servicing customers?

12. What percentage of your patrons are:

	faculty	undergraduate	graduate
Percentage of patrons			
" use of stacks			
" " " catalogs			
" " " books			
" " " serials (i.e. journals)			

Exhibit C-1

13. What is the maximum number of people you have seen around the catalog at one time? _____.
14. What percentage of your patrons use the catalog for:
- | | |
|--------------------|-------|
| 1 - 5 minutes | _____ |
| 5 - 10 minutes | _____ |
| 10 - 15 minutes | _____ |
| 15 or more minutes | _____ |
| other | _____ |
15. What is the maximum time spent at the catalog? _____
16. Is the catalog used by students and faculty combined?
- | | |
|-------|--------------------------|
| _____ | heavy (15 persons/hour) |
| _____ | medium (10 persons/hour) |
| _____ | light (3 persons/hour) |
| _____ | other |
17. How much do you rely on the public catalog's check list?
18. How often (times per day) do you phone the public catalog _____, the check list _____.
19. While waiting for permanent cards from the Catalog Department, do you make up temporary cards to use with the fanfold? Describe.

Exhibit C-1

20. If your catalog were replaced with TV, what part of your catalog would you want to keep?

_____ shelf list
_____ serials
_____ new books
_____ main entries
_____ subject cards
_____ added entries
_____ others

21. If the peak periods refer to the heaviest use of the card catalog, then

- a) When are the peak periods of semester (as example, 3rd-5th week and 13th-15th week)?
- b) When are the peak days of the week?
- c) When are the peak times of the day?
- d) When are the low periods of the term?
- e) When are the low periods of the day?

22. What other factors effect use of the catalog? (e.g. weather and campus-wide social events). How?

23. To what extent do you refer people to the public catalog, or other division catalogs for information they cannot get in your library?

Exhibit C-1

24. Are the stacks open or closed? To whom are they open?

25. If open, what percentage of your users go to the stacks directly without going to the catalog first?

26. To what extent do you encourage your patrons to use the catalog?

27. How many times per day do users ask the librarian questions that could be answered only by using the catalog if the librarian were not available?

28. Do you have any other comments or suggestions for other factors that should be considered in this study?

Exhibit C-2

LIBRARY SCHEDULE (WEEK OF MARCH 10-14, 1958)

<u>Name</u>	<u>Monday</u>	<u>Tuesday</u>	<u>Wednesday</u>	<u>Thursday</u>	<u>Friday</u>
Architecture	10, 11, 1, 2, 3, 4, 7	3	10, 3	3	3
Astronomy	3	10, 11, 1, 2, 3, 4, 7	3	3	3
Bureau of Government	2	10, 11, 1, 2, 3, 4, 7	2	2	2
Business Administration	10, 2	10, 11, 1, 2, 3, 4, 7	2	2	2
Chemistry	10, 11, 1, 2, 3, 4, 7	2	10, 2	2	2
Dental	3	10, 11, 1, 2, 3, 4, 7	3	3	3
Education	3	10, 11, 1, 2, 3, 4, 7	3	3	3
Engineering	10, 2	10, 11, 1, 2, 3, 4, 7	2	2	2
Fine Arts	11, 3	3	10, 11, 1, 2, 3, 4, 7	3	3
Mathematics	10, 2	10, 11, 1, 2, 3, 4, 7	2	2	2
Medical	10, 11, 1, 2, 3, 4, 7	3	3	3	3
Natural Science	11, 2	2	10, 11, 1, 2, 3, 4, 7	2	2
Physics	10, 2	10, 11, 1, 2, 3, 4, 7	2	2	2
Public Catalog	10, 11, 1, 2, 3, 4, 7	3	11, 3	3	3
Public Health	3	10, 11, 1, 2, 3, 4, 7	10, 3	3	3
Social Science	11, 3	10, 11, 1, 2, 3, 4, 7	3	3	3
Transportation	11, 2	2	10, 11, 1, 2, 3, 4, 7	2	2
Undergraduate	11, 3	3	10, 11, 1, 2, 3, 4, 7	3	3

Exhibit C-3

**INSTRUCTIONS FOR RECORDING DATA AT ALL LIBRARIES
EXCEPT PUBLIC CATALOG AT MAIN LIBRARY**

1. Bring with you:
 - a. a watch, preferably with sweep second hand. Check watch for correct time with time service (call 116).
 - b. pen or pencil
2. Pick up: other materials at the library. Clipboard and data sheets will be obtained from the librarians at the loan desk or from the person you are relieving. The last person taking data on a given day will turn in the sheets and clipboard to the library staff at the loan desk.
3. Method of recording data:
 - a. What data to record
 1. Fill out header information on the data sheet.
 2. Number of people at the catalog when you enter.
 3. Time of arrival of each individual, to nearest 5 second interval.
 4. Time of departure of each individual, to nearest 5 second interval.
 5. Indicate the time when no one is at the catalog.
 6. Number of people at the catalog when you leave.
 - b. How to record data
 1. In the first column on the data sheet, write down some identifying mark for each individual (such as conspicuous item of clothing).
 2. Record time of arrival in column 2: arrival time begins when the user opens the first drawer.
 3. Record departure time of the SAME individual (in column 3) when he turns to leave the catalog area after closing the last drawer.
 4. Indicate in the 4th column the time when the catalog area is empty by placing a check mark opposite the last departure time which leaves the catalog area empty.
 5. Leave columns 5 and 6 blank. They are to be used for data reduction.
 - c. Special circumstances
 1. If a person uses a drawer, pushes it in and leaves the area and returns a few minutes later to use the same drawer again, count as TWO arrivals.
 2. If you are pressed for time and miss identifying some one coming in or going out, put an X in the space for the time missed. Do not invent numbers if you miss an arrival or departure time.
 3. If more than one person arrives at one time, record each separately. Their departure times will probably differ.
4. In case of emergency and you cannot fulfill your assignment, let us know as soon as possible by phoning University extension 2096 or 2098. You may call from 8-5:00 Monday through Friday and 7-9:00 PM Sunday through Tuesday.

Exhibit C-3

5. Be sure to be at your assigned library on time (or a little early) so that the person you are relieving can make his next class. Count data for exactly the time interval assigned. It is very important that you be at the library at the beginning of each hour since the peak loads occur very shortly thereafter.

Record time accurately. It is more important to be accurate than to get all the data.

Exhibit C-4

DATA SHEET

Name _____ Page _____ of _____
 Library _____ Number of people using catalog when you
 Day _____ arrive: _____
 Your exact starting time _____ Depart: _____

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6
Identifying Characteristic	Time of Arrival	Departure time			(Leave Blank)

Exhibit C-5

Supplementary Instruction Sheet for
Public Catalog in Main Library

Due to the large number of people using the public catalog, and traffic through the area of people who will not use the catalog, the data recording task here will require a team effort. We are scheduling 5 or 6 people to each hour at the public catalog. There will be four(4) different tasks or jobs, which different members of the team must perform. These will be:

1. Recorder at Main Entrance to catalog area. (one person)
 2. Recorder at Rear Entrance to catalog area. (one person)
 3. Roving Recorders Type 1. (three persons)
 4. Roving Recorder Type 2. (one person)
1. Instruction for Recorder at Main Entrance to Catalog Area:
 - a. Location: At desk by Main Entrance to card catalog area.
 - b. What data to record (Use Main Entrance - Public Catalog Data Sheet)
 1. Fill in header information on Data Sheet.
 2. Record number of people using catalog when you begin recording data.
 3. Time of arrival of each individual into the catalog area.
(DO NOT record departure times)
 - c. How to Record Data:
 1. Record time of arrival of each individual to the nearest 5 second interval. The arrival time is the instant a person passes your desk going into the catalog area.
 2. Instructions for Recorder at Rear Entrance to Catalog Area:
 - a. Location: Near rear entrance to catalog area where you can see the four(4) entrances: (1) back stairway to Catalog Department (2) door to library staff offices (3) center stairway down to Catalog Department (4) Main Entrance to catalog area.
 - b. What Data to Record: (Use Rear Entrance - Public Catalog Data Sheet)
 1. Fill out header sheet.
 2. Departure time of any person who enters the catalog area via the Main Entrance and leaves by any of the four entrances without using the catalog. (This will consist mainly of persons using the catalog area as a hallway through the area).
 3. Arrival times of persons who enter the catalog area from any of the three(3) rear entrances and use the catalog.
 - c. How to Record Data:
 1. Under column 1 "Departure Time", record time when any individual who entered the Main Entrance leaves the catalog area without using the catalog. The time of departure is the instant the individual passes through an exit. Record time to the nearest 5 second interval.
 2. Under column 2 "Arrival Time" record time of arrival of any person who enters the catalog area from any of the three(3) rear entrances and use the catalog. Time of arrival will be when person touches the first file drawer, if in view at that time, or when the person turns into the central catalog area if the person passes out of view of Recorder. Record time to the nearest 5 second interval.

Exhibit C-5

Note, people who enter the catalog area through any of the three(3) rear entrances and who do not use the catalog will not appear on your sheet. THIS IS AS IT SHOULD BE:

3. Instructions for Roving Recorders, Type 1:
 - a. Duties - To record arrival and departure times of a sample of catalog users, watching one user at a time.
 - b. Location:
 1. "Ready" position:
 2. Stand near cloak closet when waiting to record a holding time.
 3. When watching a card catalog user, stand where you can see the person being as inconspicuous to that person as possible.
 - c. What Data to Record: (Use standard Data Sheet)
 1. Fill our header except for number of people using catalog - leave these two spaces blank.
 2. Select the next card catalog user to arrive through any entrance when you are in the "ready" position, and record the time when he touches the file drawer.
 3. Record the time of departure of the catalog user you are watching. Then return to "ready" position to time another user.
 - d. How to Record Data:
 1. In the first column on the data sheet, write down some identifying mark for each individual (such as conspicuous item of clothing)
 2. Record time of arrival in column 2: arrival time begins when the user opens the first drawer.
 3. Record departure time of the SAME individual (in column 3) when he turns to leave the catalog area after closing the last drawers.
 4. Do not use column 4.
 5. Leave columns 5 and 6 blank. They are to be used for data reduction.
 - e. Special instructions if holding time exceeds 5 minutes. If the person you are watching has continued to use the catalog for 5 minutes, contact the Type 2 Roving Recorder and transfer the responsibility of timing this user to him by doing the following:
 1. Indicate the person to the Type 2 Recorder.
 2. Give the arrival time to the the Type 2 Recorder.
 3. Draw a line through that arrival time on your data sheet.
 4. If the Type 2 Recorder is currently watching a "short time user" pick up "short time user" arrival time on your sheet and follow him until he leaves. If Type 2 Recorder is not watching a short timer, go back to "ready" position.
4. Instructions for Roving Recorder, Type 2:
 - a. Duties:
 1. Function as a Roving Recorder, Type 1, until contacted by a Type 1 Recorder to take over responsibility for watching a person who has used a catalog 5 minutes.
 2. Assume responsibility for watching all persons who have been using the catalog for 5 minutes. (If operating as a Type 1 Recorder at

Exhibit C-5

the time, transfer the short term person being watched to the Type 1 Recorder). Give him the arrival time and draw a line through the appropriate time on your sheet.

b. Location - same as Roving Recorder, Type 1.

c. What Data to Record:

(same as Roving Recorder, Type 1.)

d. How to Record data (Use standard data sheet)

(same as Roving Recorder, Type 1)

It is desirable, but not necessary to record departures to the nearest 5 second interval. If you miss a departure when you are watching several people, record the departure time as accurately as you can. (The nearest 30 second interval is still o.k.)

e. Return to Type 1 method of operation if there is no demand for the Type 2 function, i.e. no people being timed have been there for more than 5 minutes.

Exhibit C-6

DATA SHEET

Main Entrance Public Catalog

Name _____ Page _____ of _____
Day _____ Number of people using catalog when
Your exact starting time _____ you start _____

Arrival Time	(Leave Blank)	Arrival Time	(Leave Blank)	Arrival Time	(Leave Blank)

Exhibit C-7

DATA SHEET

Rear Entrance Public Catalog

Name _____

Page _____ **of** _____

Day _____

Your exact starting time _____

Departure Time	Arrival Time	Departure Time	Arrival Time	Departure Time	Arrival Time

APPENDIX D

MATHEMATICAL TECHNIQUES USED IN ESTIMATING THE NUMBER
OF MONITORS AND CAMERAS REQUIRED

1. INTRODUCTION

The problem of determining the number of cameras and monitors required to replace card catalogs in divisional libraries centered principally around the question of determining the minimum equipment needed such that access time to the central catalog from any library would be held within reasonable limits. Similar problems have occurred in the design of telephone systems, in determining the number of toll booths needed at entrances to toll highways, and in determining the dock facilities needed in seaports, to mention a few examples. Consequently, the mathematical theory applicable to a limited class of such problems was available for the present case. The construction of mathematical models of waiting-line processes, however, can become quite complex. Since the purpose of the present study was to provide an estimate of the amount of Telereference equipment needed, only the simplest mathematical formulation was justified.

The essential characteristics of any queuing problem are that units (people, cars, ships) arrive in some pattern or distribution through time to a service facility (telephone exchange, toll booth, seaport) where they are serviced, and then depart. The time required to service a unit may be constant or may take the form of some time distribution. If the service facility is occupied when a unit approaches for service, the unit must wait, thus forming a waiting line.

One of the simplest mathematical queuing models results when the rate of arrivals to a service facility takes the form of a Poisson distribution, and the distribution of service times takes the form of a negative exponential distribution. The Poisson distribution can be expressed as follows:*

$$P(k) = P(k; \lambda t) = e^{-\lambda t} \frac{(\lambda t)^k}{k!} \quad (1)$$

In terms of the problem at hand, this equation expresses the probability of (k) arrivals in a fixed interval of time, (t), where (λt) is the mean of the distribution, and (λ) is the average rate of arrivals per unit time.

The negative exponential distribution can be written:

$$P(t) = e^{-\mu t} = e^{-\frac{t}{M}} \quad (2)$$

This may be interpreted as the probability that any servicing time will exceed

* Feller, reference 4, page 148.

time (t), where (μ) is the mean servicing rate and (M) is the mean servicing time (holding time).

The Poisson distribution of arrival rates generally occurs in waiting-line situations when the time of any arrival is independent of the time of any other arrival. The negative exponential distribution of servicing time occurs when the time required to complete the service on any one unit is independent of the time already spent in servicing that unit.

2. VERIFICATION OF HYPOTHESES CONCERNING ARRIVAL RATES AND HOLDING TIME DISTRIBUTION

After preliminary investigation of the pattern of card catalog use in divisional libraries, it appeared that the above two conditions might exist regarding the rate of arrivals to card catalogs and the time patrons use the catalog. The data collection plan discussed in Appendix C was thus designed to obtain the information necessary to test these two hypotheses. The test plan was also designed to obtain a measure of the peak rate of arrivals to each catalog, and to indicate the fluctuations in the rate from hour to hour.

The first hypothesis, that the rate of arrivals to each catalog can be closely approximated by the Poisson distribution, was tested as follows. If the distribution of arrival rates takes the form of a Poisson distribution, as shown in equation (1), then the distribution of intervals between arrivals takes the form of a negative exponential distribution similar to the distribution of servicing times:

$$P(t) = e^{-\lambda t} = e^{-\frac{t}{L}} \quad (3)$$

This expresses the probability that the time between arrivals will exceed time (t), where (λ) is the average arrival rate as in (1) above, and (L) is the average time between arrivals.

The corresponding expected number of intervals between arrivals, $n(t)$, which exceed a time interval (t), is given by

$$n(t) = Ne^{-\lambda t} \quad (4)$$

where (N) is the total number of intervals between recorded arrivals.

The distribution of intervals between arrivals, taken directly from the recorded data, was plotted for each library studied in cumulative form on semi-logarithmic graph paper. A negative exponential distribution plotted in this way appears as a straight line. The data from each library were fitted closely with a straight line as shown in Fig. 6 of the text for three of the libraries studied. This technique provided an indication of the validity of the hypothesis.

To further test the hypothesis, the Chi-square test, a more rigorous

test for "goodness of fit" between an observed experimental distribution and a theoretical distribution, was conducted for several of the libraries. The Chi-square (χ^2) distribution is defined as follows:*

$$\chi^2 = \sum_1^k = \frac{(fo_i - fe_i)^2}{fe_i}$$

where fo_i and fe_i denote the i^{th} pair of observed and expected frequencies respectively, and k is the number of pairs of frequencies compared. The expected number of occurrences in a given time interval (t_i, t_{i+1}) can be computed from (4) above.

$$fe_i = n(t_i) - n(t_{i+1}) = N (e^{-\lambda t_i} - e^{-\lambda t_{i+1}})$$

where t_i, t_{i+1} are the end points of the i^{th} time interval. For use in these and subsequent calculations, the value of the parameter λ , the average arrival rate, was estimated from the recorded data.**

The probability that χ^2 assumes a value greater than χ_p^2 is equal to $p\%$ where $p\%$ is the level of significance for the test. If an observed distribution corresponds closely to a theoretical distribution, the observed frequencies, fo_i , will correspond closely to the expected frequencies fe_i , and the value of χ^2 will be small. The probability that a value of χ^2 will be exceeded by chance alone, then, is equal to p . It is general practice to use a level of significance for the test such that the hypothesis is rejected whenever $p \leq 5\%$. If $\chi^2 \leq \chi_p^2$ with $p = 5\%$, then the hypothesis being tested is not rejected; but if $\chi^2 > \chi_p^2$, with $p = 5\%$, the hypothesis is normally rejected. Values of χ_p^2 for different values of p and for different numbers of degrees of freedom are available in table form.***

* Hoel, reference 6, page 164.

** It can be shown that an unbiased estimate of λ is $\frac{N-1}{\sum_{i=t_0}^N \Delta t_i}$, where N

is the total number of arrivals and Δt_i is the time interval between the i^{th} and $(i+1)^{\text{st}}$ arrivals.

*** cf. Cramér, reference 3, page 275.

Exhibit D-1 shows the calculations used in applying the Chi-square test to determine the "goodness of fit" of the observed distribution of intervals between arrivals to a theoretical negative exponential distribution for arrivals to the main catalog in the Undergraduate Library. The value of χ^2 shown (20.23) is representative of the libraries studied. With 13 degrees of freedom, this value of χ^2 corresponds to a level of significance of approximately 10% for the test, well within the acceptance region, assuming rejection would normally be made at the 5% level. The hypothesis that the population from which the sample was drawn is negative exponentially distributed cannot, therefore, be rejected.

Since the distribution of intervals between arrivals takes the form of a negative exponential distribution, the hypothesis that the rate of arrivals is Poisson distributed is also verified because of the direct relationship between the two distributions.

The second hypothesis, that the distribution of holding times can be approximated by a negative exponential distribution, was tested in the same way as the first hypothesis. The observed distribution was first plotted in cumulative form using semi-logarithmic scales, as shown in Fig. 7 of the text. It was possible to fit the observed data from the two small libraries quite closely with one straight line. However, the data from the Public Catalog and Undergraduate Main Catalog are better fitted with two straight lines. This suggests that two populations, each represented by truncated negative exponential distributions with different means, add to form the observed distribution.

To determine if the holding time distribution might nevertheless be reasonably approximated by one negative exponential distribution with the observed mean, the Chi-square test was again employed. The mean servicing rate, μ , used in this and subsequent calculations was estimated from the recorded data*. Exhibit D-2 shows the table of calculations for the Undergraduate Library Main Catalog. The value of the χ^2 obtained in the first three cells (for holding times of 0 to 1.5 minutes) indicates that the observed distribution deviates significantly from the theoretical negative exponential distribution for this range of holding times. From 1.5 to 9.5 minutes, the value of χ^2 is less than χ_p^2 for $p = 5\%$. Approximately 60% of the holding times recorded fall within this range. Despite the deviation from the theoretical distribution in the first three cells, a negative exponential holding time distribution is a fair approximation to the observed data. The assumption is certainly adequate in terms of the degree of accuracy needed in the estimates of equipment required. This assumption was therefore used throughout in the calculations of the number of cameras and monitors required.

Subsequent examination of the distributions of holding time using similar graphical techniques and the Chi-square test indicates that the distribution

* The mean servicing rate $\mu = \frac{N}{\sum_{i=1} \Delta t_i}$ where N is the total number of catalog

users and Δt_i is the servicing time (holding time) of the i^{th} person. The average holding time $M = 1/\mu$.

Exhibit D-1

Undergraduate Library (Main Catalog) Distribution of Intervals Between Arrivals
 Chi-square Test
 Negative Exponential Fit

$N = 663$
 $\lambda = .80$

Cell	Time	$e^{-\lambda t}$	f_o	f_e	Cum f_e	$(f_o - f_e)^2$	$\frac{(f_o - f_e)^2}{f_e}$
1	.33 min	.76797	176	153.8	509.2	492.84	3.21
2	.67	.58508	127	121.3	387.9	32.49	.27
3	1.0	.44933	77	90.0	297.9	169.00	1.87
4	1.33	.34507	61	69.1	228.8	65.61	1.20
5	1.67	.26290	48	54.5	174.3	42.25	.78
6	2.0	.20190	36	40.4	133.9	19.36	.48
7	2.33	.15505	24	31.1	102.8	50.41	1.62
8	2.67	.11813	35	24.5	78.3	110.25	4.50
9	3.0	.09072	20	18.2	60.1	3.24	.18
10	3.33	.06967	9	13.9	46.2	24.01	1.73
11	3.67	.05308	14	11.0	35.2	9.00	.82
12	4.0	.04076	8	8.2	27.0	.04	.01
13	4.33	.03130	6	6.2	20.8	.04	.01
14	5.0	.01832	5	8.7	12.1	13.69	1.57
15	30.0	$10^{-9} \times 4096$	17	12.1	0.0...	24.01	1.98

$\chi^2 = 20.23$
 Degrees of freedom = 13
 Level of significance $\approx 10\%$

Exhibit D-2

Chi-squared Test
Undergraduate Library (Main Catalog) Holding Time Distribution
Negative Exponential Fit

$\mu = .330$
 $N = 658$

Cells	t	$e^{-\mu t}$	Cum $f_e =$ $N e^{-\mu t}$	f_o	f_e	$(f_o - f_e)^2$	$\frac{(f_o - f_e)^2}{f_e}$
1	.5	.85642	563.2	64	94.8	948.64	10.00
2	1.0	.71892	473.1	119	90.1	835.21	9.27
3	1.5	.60957	401.4	107	71.7	1,246.09	17.38
4	2	.51685	340.2	66	61.2	23.04	0.38
5	2.5	.43823	288.2	61	52.0	81.0	1.56
6	3	.37158	244.8	38	43.4	29.16	0.67
7	3.5	.31506	207.3	31	37.5	42.25	1.13
8	4	.26714	175.7	35	31.6	11.56	0.37
9	4.5	.22650	149.4	22	26.3	18.49	0.70
10	5	.19205	126.3	17	23.1	37.21	1.61
11	5.5	.16284	107.3	12	19.0	49.0	2.58
12	6	.13807	90.8	18	16.5	2.25	0.14
13	6.5	.11707	77.0	6	13.8	60.84	4.41
14	7	.09926	65.1	6	11.9	34.81	2.93
15	7.5	.08416	55.3	5	9.8	23.04	2.35
16	8.5	.06051	40.1	11	15.2	17.64	1.16
17	9.5	.04350	29.0	6	11.1	26.01	2.34
18	30	.00005	.03	28	28.97	.94	0.03

$\chi^2 = 22.36$
 Degrees of freedom = 13
 Level of significance = 5%

of holding times in all libraries studied can be more closely fitted with a lognormal distribution. The frequency function has the form*:

$$f(x) = \frac{1}{\sqrt{2\pi} \sigma(x-a)} e^{-\frac{[\ln(x-a) - \mu]^2}{2\sigma^2}}$$

A logarithmic-probability plot of the data from three libraries is shown in Fig. 8 of the text. The lognormal distribution plotted in this way gives a straight line. The data from each of the three libraries shown can be very closely fitted with a straight line. By transforming the lognormal distribution into the equivalent form of the standard normal distribution, the Chi-square test was performed. The equivalent standard normal distribution function can be expressed as

$$f(Z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\frac{\ln C - \mu}{\sigma}} e^{-\frac{Z^2}{2}} dZ$$

where

$$Z = \frac{\ln C - \mu}{\sigma}$$

where C is the end point of the time intervals used and μ and σ are the mean and standard deviation respectively of the normal distribution. The estimates of μ and σ were determined from graphs similar to Fig. 8 where:

$$\mu = \ln \xi_{50\%}$$

$$\sigma = \ln \frac{1}{2} \left[\frac{\xi_{50\%}}{\xi_{16\%}} + \frac{\xi_{84\%}}{\xi_{50\%}} \right]$$

Exhibit D-3 shows the calculations of the Chi-square test for the lognormal distribution of holding times for the Undergraduate Library Main Catalog. Here, the same observed data shown in Exhibit D-2 are again presented. However, the "goodness of fit" of this same data to the lognormal distribution is much better than the fit to the negative exponential distribution. The level of significance of the test for the lognormal fit is 50% (with 13 degrees of freedom) over the entire range of the data compared to a level of significance of 5% obtained with the negative exponential distribution over the range of data from 1.5 to 30 minutes.

Although the lognormal distribution provides a better approximation to the observed data than the negative exponential distribution, the use of the negative exponential distribution in calculating the number of cameras and

* cf. Cramer, reference 3, page 118.

Exhibit D-3

Chi-square Test
 Undergraduate Library (Main Catalog) Holding Time Distribution
 Log-normal Fit

M = .588
 S = .977
 N = 658

Cell	Time	Log Time	Log t-M	Log $\frac{t-M}{s} Z_1$	(.5)-Area, Z_1	$(\Delta A_1) - (\Delta A_{j-1})$	fe = MΔA	fo	$(fo-fe)^2$	$\frac{(fo-fe)^2}{fe}$
1	.5	-.6515	-1.2395	-1.268	.1024	.1024	67.4	64	11.56	.1715
2	1.0	0	-.5880	-.6018	.2736	.1712	112.6	119	40.96	.3638
3	1.5	.4055	-.1825	-.1867	.4259	.1523	100.2	107	46.24	.4615
4	2	.6932	.1052	.1076	.5430	.1171	77.1	66	123.21	1.598
5	2.5	.9163	.3283	.3360	.6316	.0886	58.3	61	7.29	.1250
6	3	1.0986	.5106	.5226	.6995	.0679	44.7	38	44.89	1.0042
7	3.5	1.2528	.6648	.6804	.7517	.0922	34.3	31	10.89	.3174
8	4	1.3863	.7983	.8170	.7930	.0413	27.2	35	60.84	2.2367
9	4.5	1.5041	.9161	.9376	.8259	.0329	21.6	22	0.16	.0074
10	5	1.6094	1.0214	1.045	.8520	.0261	17.2	17	.04	.0023
11	5.5	1.7048	1.1168	1.143	.8735	.0215	14.1	12	4.41	.3128
12	6	1.7918	1.2038	1.232	.8910	.0175	11.5	18	42.25	3.6749
13	6.5	1.8718	1.2838	1.314	.9056	.0146	9.6	6	12.96	1.350
14	7	1.9459	1.3579	1.389	.9176	.0120	7.9	6	3.61	.4569
15	7.5	2.0149	1.4269	1.460	.9279	.0103	6.8	5	3.24	.4764
16	8.5	2.1401	1.5521	1.588	.9439	.0160	10.5	11	.25	.0238
17	30	3.4012	2.8132	2.879	.9980	.0541	35.6	40	19.36	.292

$\chi^2 = 12.874$
 Degrees of Freedom = 14
 Level of significance $\approx 50\%$

monitors required is justified since this distribution adequately approximates the observed data for purposes of the equipment estimates required,* and its use simplifies computation.

3. CALCULATION OF NUMBER OF MONITORS REQUIRED

The first problem in attempting to estimate equipment requirements was the choice of some proper design criterion. In general, it was felt that enough equipment should be available such that the waiting time expected in any library at any time would be within reasonable limits. Preliminary investigation revealed that it was clearly infeasible to provide enough equipment such that the waiting time would be as short as that currently experienced with no mechanization of the catalog. Choosing design criteria was complicated by the fact that the rate of arrivals to each catalog studied varied over a considerable range from hour to hour, as shown in Figures 4A, 4B, 4C and 5A and in Table 3 of the text. A large amount of equipment would be required to keep the waiting time to some constant level during periods of peak demand; yet, if this equipment were provided, much of it would be idle during periods of low demand. A similar problem has been faced by telephone companies for many years. An optimum balance between the cost of equipment and the "cost" of waiting time is obviously required. Over the years, a satisfactory solution has been reached by the telephone company.** With considerable additional work, some form of optimum balance could likewise have been achieved in the present case, but such refinement was not justified in the present study.

The only feasible method of determining the equipment in the present case was to choose design criteria essentially on a subjective basis. After discussion with members of the University Library staff the following criteria were chosen:

1. On the average, the waiting time (for access to a monitor) should not exceed one minute in any library.
2. During the peak ten minute period of the peak hour, the average waiting time for access to a monitor should not exceed 5 minutes in any library.

In calculating the number of monitors needed in accordance with these criteria, the following assumptions were made:

1. The distribution of arrival rates corresponds to the Poisson distribution during any time interval considered.
2. The distribution of servicing rates (holding time rates) corresponds to a negative exponential distribution. It is further assumed that the mean holding time does not change during different time intervals considered, even though the

* An alternative method might have been to use the Erlang-2 or Erlang-3 distribution of servicing times as discussed in Morse, reference 8, pages 39-58.

** Goode and Machol, reference 5, chapter 13.

arrival rates may be different.

3. After obtaining a monitor, it is assumed that zero time is required to obtain a connection to a camera and to have the required drawer brought to a camera for viewing. This assumption means that any waiting time required depends only on the demand for monitors and not on further delays within the system.

In calculating the number of monitors required, the monitors may be considered as servicing channels associated with a queuing situation. For the case where there is a single channel (one monitor), the probability of a queue of length (N) forming is given by*

$$P(N) = \left(\frac{\lambda}{\mu}\right)^N (1 - \frac{\lambda}{\mu}) = \left(\frac{\lambda}{\mu}\right)^N P_0, \text{ if } \frac{\lambda}{\mu} < 1$$

where λ and μ are the mean arrival and servicing rates respectively, as defined in section 2 above, and P_0 is the probability of a waiting line of zero length (or no waiting line) forming. The ratio $(\frac{\lambda}{\mu})$, called ρ , is a measure of the intensity with which the facility is used. The condition $\rho < 1$ is necessary for the length of the waiting line to be finite.

The corresponding expected waiting time t_w (to obtain a monitor) is given by**:

$$\bar{t}_w = \frac{1}{(\mu - \lambda)} - \frac{1}{\mu} = \frac{\lambda}{\mu(\mu - \lambda)}$$

When more than one channel is required to service the demand properly, the probability of a queue of length N forming is given by***:

$$P(N) = P_0 \frac{(\lambda/\mu)^N}{N!} = P_0 \frac{\rho^N}{N!} \quad (\text{for } N \leq S)$$

and

$$P(N) = P_0 \frac{(\lambda/\mu)^N}{S! S^{N-S}} \quad (\text{for } N \geq S)$$

where****

$$P_0 = \frac{1}{\sum_{N=0}^{S-1} \frac{(\lambda/\mu)^N}{N!} + \left[\frac{(\lambda/\mu)^S}{S!(1 - \lambda/\mu S)} \right]}$$

* Churchman, reference 2, page 397.

** cf. Churchman, reference 2, page 402.

*** cf. Churchman, reference 2, page 405.

**** cf. Churchman, reference 2, page 406.

where S is the number of channels. The condition $(\frac{\lambda}{\mu}) < S$ is necessary for the length of the waiting line to be finite. The corresponding average waiting time is given by*:

$$\bar{t}_w = \frac{P_o}{\mu S(S!) [1 - (\frac{\lambda}{\mu S})]^2} (\frac{\lambda}{\mu})^S$$

Using the above equations, the number of monitors was first determined for each library such that $\bar{t}_w \leq 1$ minute, based on the average arrival rate recorded during one full day's observations (see Table 3, column 2, text) and on the average holding time based on all data recorded for each library. (See Table 3, column 4, text). The number of monitors required in each library, such that $\bar{t}_w \leq 5$ minutes during the peak ten minutes of the peak hour observed at each library, was then calculated. The number of monitors required to meet both criteria calculated in this manner is shown in Exhibit D-4, column 1, resulting in a total of 52 monitors. In the process of making these calculations, it was noted that if the second criterion was relaxed such that $\bar{t}_w \leq 10$ minutes, the number of monitors required, based on the formulas used, would be reduced by one unit each in only four libraries, as shown in Exhibit D-4, column 2, resulting in a total of 48 monitors. If the second criterion was completely removed, the number of monitors required would reduce to 36, as shown in Exhibit D-4, column 3.

Actually, the additional monitors required to satisfy the second (peak demand) criterion cannot be predicted accurately, using the above equations. These equations are intended to depict the resulting queues in a steady-state situation over a relatively long period of time. The peak demands observed in all libraries was quite short lived, so that the queues would not have time to build up to the extent predicted by the formulas used. In addition, since the peak demands can be expected to occur only several times per week at each library, only a small fraction of catalog users would actually have to wait more than 5 minutes during any peak demand period if 48 monitors were provided, as shown in Exhibit D-4, column 2. It thus appears that the minimum number of monitors required to meet the two criteria chosen is 48 rather than 52 units.

4. CALCULATION OF NUMBER OF CAMERAS

Since all divisional libraries do not experience peak demand periods at the same time, the composite demand on a central system would not require a camera for every monitor. To estimate the minimum number of cameras, consistent with the criteria adopted in calculating the required number of monitors, the total demand expected on the central system at any time was estimated by recording data simultaneously at all library catalogs studied during the three-hour period when the system peak was expected to occur, as discussed in Appendix C.

The magnitude and duration of the system peak recorded is shown in Fig. 5B

* cf. Churchman, reference 2, page 406.

Exhibit D-4

Number of Monitors Required Based on Different Waiting Time Criteria

Library	$\bar{t}_v \leq 1$ minute during full day	$\bar{t}_v \leq 1$ minute during full day	$\bar{t}_v \leq 1$ minute during full day
	$\bar{t}_v \leq 5$ minutes during 10 minute peak	$\bar{t}_v \leq 10$ minutes during 10 minute peak	No Restriction on \bar{t}_v during peak
Architecture	2	1	1
Astronomy	1	1	1
Bureau of Government	1	1	1
Business Administration	2	2	2
Chemistry	1	1	1
Dentistry	1	1	1
Education	2	2	2
Engineering	3	3	2
Fine Arts	1	1	1
Mathematics	2	2	2
Medical	3	3	2
Natural Resources	3	3	2
Physics	2	1	1
Public	13	13	8
Public Health	2	1	1
Social Science	3	2	2
Transportation	1	1	1
Undergraduate: Basement	1	1	1
Undergraduate: Main Floor	5	5	3
Undergraduate: 1st Floor	1	1	1
Undergraduate: 2nd Floor	2	2	1
TOTAL	52	48	36

of the text. Based on this data, the system peak demand was judged to occur during the twenty-minute interval from 3:00 to 3:20 p.m. The combined demand for monitors during this time interval was used as the basis for calculating the number of cameras needed. The system utilization intensity factor

$\rho_S = \left(\frac{\lambda}{\mu}\right)$ was determined by combining similar factors for all libraries as observed during this twenty minute period as

$$\rho_S = \sum_{i=1}^{21} \frac{\lambda_i}{\mu_i}$$

This value was computed to be: $\rho_S = 20.43$, which indicates the average combined demand for monitors during the twenty-minute system peak. If fewer monitors were available, a queue would build up rapidly, tending to infinity if the same conditions persisted over a long time. The lower bound on the number of cameras required is thus 21.

At this point a new problem arises. Based on demand conditions in individual libraries, it has already been determined that 48 monitors will be needed. If the number of monitors exceeds the number of cameras, a two-stage waiting line begins to form. After waiting for access to a monitor, the user again would have to wait to obtain a camera. This is contrary to the original assumptions made in calculating the number of monitors required. The problem as described, however, would be very difficult to handle analytically, in that the character of the waiting line situation between cameras and monitors is difficult to describe. A solution could be obtained using Monte Carlo techniques*, but was not justified for purposes of the present study.

To surmount this obstacle, an additional simplifying assumption must be made to proceed with the calculation of the number of cameras. The assumption made is that the number of monitors available is very large (infinite) so that the only waiting time is now caused by the restricted number of cameras provided. The number of cameras to be provided can then be adjusted upward until the probability of a waiting line forming is very small. The probability that a queue of length N will form is given by

$$P(N) = \frac{P_0 \left(\frac{\lambda}{\mu}\right)^N}{N!}$$

The probability that more than N people will be in the queue (the queue includes people using cameras plus those waiting) is thus $(1 - \sum_{N=0}^{\infty} P_N)$. If 25 cameras are provided, the probability that there will be more than 25 people in the queue, (or that one or more persons will be waiting) was calculated to be .2007. If 30 cameras are provided, the probability of a waiting line forming was calculated to be .018. The probability of needing more than X number of cameras during the system peak if 30 cameras are provided was shown previously in Fig. 3 of the text. By providing enough cameras so that the proba-

* cf. Churchman, reference 2, page 407.

bility of a waiting line forming, due to lack of cameras is very small; the probability of a waiting line forming between cameras and monitors can be assumed negligible.

A similar result can be obtained* by assuming that the rate of arrivals to cameras is Poisson distributed with mean $\rho_S = 20.43$. The average demand for cameras is thus 20.43. The number of cameras which must be provided can be computed for different levels of the probability that the demand exceeds the number of cameras available. The number of cameras required so that the demand is satisfied 99% of the time (or that a queue will form 1% of the time) is given by

$$\begin{aligned} \text{No. of Cameras} &= E(x) + 2.33 \sqrt{E(x)} \\ &= 20.43 + (2.33)(4.52) \\ &= 30.96 \end{aligned}$$

which corresponds very closely to the 30 cameras calculated for the queue forming 1.8% of the time.

5. SUMMARY

The preceding methods of calculation indicate the manner in which the number of cameras and monitors was estimated. The estimates are presented in Table 1 of the text in terms of three application alternatives. It should be clearly evident that the estimated equipment is dependent almost entirely on the design criteria chosen. A willingness to permit longer waiting times will result in a lower estimated amount of equipment required. For instance, an alternative design criterion given consideration was that the average waiting time during the peak hour should not exceed one minute. Using this criterion, the number of monitors required would have been reduced to a total of 39, but waiting times during shorter peaks would likely be longer than 5 minutes.

The design criteria chosen represent an attempt to provide a number of monitors and cameras large enough so that the performance of the Telereference system would be roughly comparable to that of the present system in terms of access time to the catalog. It was assumed that no time is involved in operating the monitors, giving instructions to the librarian at the cameras, or having card drawers brought to the cameras. When additional information is available concerning the actual time required to perform these other operations necessary to the Telereference system, the results of the present analysis can then be modified easily to provide a comparison of the operating efficiencies of the two systems.

* cf. Goode and Machol, reference 5.

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