DOCUMENT RESUME

ED 126 879	52	IR 003 792

AUTHOR	Rouse, William B.; Rouse, Sandra H.
TITLE	A Mathematical Model of the Illinois Interlibrary Loan Network. Project Report Number 4.
INSTITUTION	Illinois Univ., Urbana. Coordinated Science Lab.
SPONS AGENCY	Bureau of Libraries and Educational Technology (DHEW/OE), Washington, D.C.; Illinois State Library, Springfield.
REPORT NO	R-T-28
PUB DATE	Jun 76
NOTE	27p.; For related documents see ED 107 287, 101 667 and IR 003 571
EDRS PRICE	MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS	Book Catalogs; Catalogs; Computer Oriented Programs; Costs; *Interlibrary Loans; Library Automation; Library Circulation; *Library Networks; *Mathematical Models; Microforms
IDENTIFIERS	ILLINET; Illinois; *Illinois Interlibrary Loan Network

ABSTRACT

Relatively recent developments, ranging from microfilm catalogs to networked circulation systems, have the potential of removing much of the uncertainty from the routing of interlibrary loan requests. The opportunity of purchasing location and availability information changes the performance of a model interlibrary loan network. Data collected in Illinois show that location information is very valuable and filmed catalogs may be worth several hundred dollars per year to the Illinois Interlibrary Loan Network (ILLINET). Illinois experience also indicates that local availability information, obtained from an automated circulation system, has minimal value, but the same information, made available throughout a network, reduces the time to satisfy a request. (Author/PF)

A MATHEMATICAL MODEL OF THE ILLINOIS INTERLIBRARY LOAN NETWORK

Project Report No. 4

Submitted to

Illinois State Library

William B. Rouse

Sandra H. Rouse

Coordinated Science Laboratory

University of Illinois at Urbana-Champaign

Urbana, Illinois 61801

June 1976

This research was made possible by a grant from the Illinois State Library under the Illinois Program for Title I of the Federal Library Services and Construction Act.

FOREWARD

This is the fourth in a series of reports resulting from a research grant to the Coordinated Science Laboratory of the University of Illinois at Urbana-Champaign. The sponsor of the grant is the Illinois State Library under the Illinois Program for Title I of the Federal Library Services and Construction Act.

Previous reports can be purchased in hardcopy or microfiche from ERIC Document Reproduction Service, Computer Microfilm International Corp. (CMIC), 2020 14th Street North, Arlington, Virginia 22201

1. W. B. Rouse, J. L. Divilbiss, and S. H. Rouse, A Mathematical Model of the Illinois Interlibrary Loan Network: Project Report No. 1, Coordinated Science Laboratory Report No. T-14, University of Illinois at Urbana-Champaign, November 1974, ERIC No. ED 101 667.

   Includes a review of the literature on interlibrary loan networks, a flow chart description of the Illinois network, a review of methodologies appropriate to modeling networks, an initial model, and discussion of alternative computer and communication technologies.

2. W. B. Rouse, J. L. Divilbiss, and S. H. Rouse, A Mathematical Model of the Illinois Interlibrary Loan Network: Project Report No. 2, Coordinated Science Laboratory Report No. T-16, University of Illinois at Urbana-Champaign, March 1975, ERIC No. ED 107 287.

   Includes a derivation of the mathematical model (version no. 2) and its applications to a hypothetical network so as to illustrate various policy issues. A summary of the User's Manual for the interactive program of the model is also included.

3. W. B. Rouse and S. H. Rouse, A Mathematical Model of the Illinois Interlibrary Loan Network: Project Report No. 3, Coordinated Science Laboratory Report No. T-26, University of Illinois at Urbana-Champaign, April 1975, ERIC No. not yet available.

   Includes a detailed analysis of the Illinois network based on data obtained from the Illinois State Library and from the Library Research Center at the University of Illinois. Several alternative request routing policies are considered and specific recommendations are discussed.

TABLE OF CONTENTS

INTRODUCTION AND SUMMARY

In our previous reports, we have emphasized the formulation of request routing policies on the basis of probabilistic descriptions of the abilities of various sources to satisfy requests. However, relatively recent developments have the potential of removing much of the uncertainty from request routing. These developments range from the not so recent book form or film catalogs to the much more recent shared cataloging networks such as OCLC and networked circulation systems such as the CLSI network in northern Illinois. The purpose of this report is to assess the impact of these and other computer technology alternatives on the interlibrary loan activities of the Illinois Library and Information Network. As usual, we will try to keep our analysis as general as is possible while still addressing the issues as they specifically affect Illinois.

Instead of discussing OCLC, CLSI, etc. directly, let us simplify the problem to a few basic issues. Routing of interlibrary loan (ILL) requests can be greatly facilitated by two types of information: location and availability. In other words, given a particular ILL request, we need to know: Who owns the desired item? Is it available for ILL purposes? If one has the opportunity to purchase location and/or availability information, then two questions arise. First, how will this information affect network performance? Second, how much should one be willing to pay for this information? The analysis presented in this report is aimed at providing a methodology for answering these questions in general while also providing specific answers for Illinois.

We will proceed as follows. In the next section, the alternative computer technologies will be verbally and graphically described as they affect network operations. The following section is devoted to deriving the appropriate equations. The reader can skip this section with little loss of continuity. A final section will consider the specific results for Illinois based upon data presented in Project Report No. 3.

Briefly summarizing the results presented in this report, we have concluded that location information is very valuable and filmed catalogs may be worth several hundred thousand dollars per year to ILLINET. If the OCLC data base includes appropriate information for local retrieval of items (e.g., call numbers), then this data base may be an attractive location tool for the network. However, if such information is not available, filmed catalogs are probably a better investment. Local availability information* as might be obtained via a computerized circulation system has minimal value but we believe this to be an artifact of the data employed and urge collection of more appropriate data. Network availability information reduces average time to satisfy a request since only a single Center must process the request. Finally, many of our conclusions are dependent on the reimbursement structure in Illinois. However, the methodology presented in this report is capable of considering alternative reimbursement schemes and predicting the results of their implementation.

---

* Local availability information means that this information can only be accessed at the particular library to which the information applies. On the other hand, network availability information means that this information can be accessed from any point in the network.

DESCRIPTION OF THE ALTERNATIVES

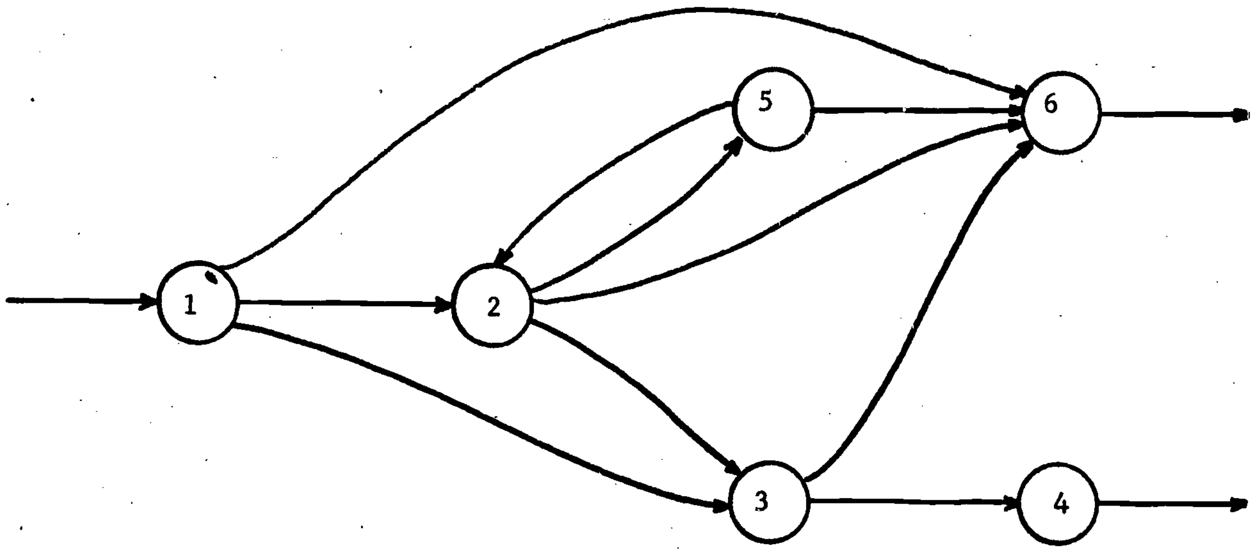
Location and availability information not only affects the routing of requests, it also affects the internal flow of requests within a resource library. To consider these effects, we will use the description of internal library operations shown in Figure 1. This figure is identical to that discussed in Project Report No. 2 (page 32) with the exception that direct transitions from process 1 to process 6 are now allowed. The reason for this addition will be obvious as our discussion proceeds.

Throughout the analyses presented in this report, we will assume that all requests enter a library previously verified. Thus, transitions to process 5 are unnecessary. This simplification makes the issues much more straightforward when comparing alternatives. Otherwise, differences in performance among alternatives would not be solely due to the impact of the alternatives but instead would also depend on the availability of verification tools at the requesting libraries. Further, as evidenced by the data in Project Report No. 3 (page 28), almost 90% of all requests in Illinois satisfy this assumption.

Thus, the allowable transitions are 1-2, 1-3, 1-6, 2-3, 2-6, 3-4, and 3-6. Let α_{ij} be the probability of transitioning from process i to process j. Now, let us consider how the various alternatives affect these transition probabilities.

If we have no location or availability information, then $\alpha_{12} = 1$, $\alpha_{23} = o_{ij}$, $\alpha_{26} = 1-o_{ij}$, $\alpha_{34} = a_{ij}$, $\alpha_{36} = 1-a_{ij}$ and the remaining α's are zero. Recall from Project Report No. 3 (page 5) that o_{ij} is the probability that resource library i owns an item in request class j* while a_{ij} is the

* Assuming the request has been verified.



1 = In-Process Request

2 = Search

3 = Obtain Desired Item

4 = Out-Process Desired Item

5 = Verification

6 = Out-Process Request

FIG. 1: INTERNAL OPERATION OF A RESOURCE LIBRARY

probability that an owned item is available.

If we introduce a computerized circulation system at process 2, then $\alpha_{23} = a_{ij}o_{ij}$, $\alpha_{26} = 1 - a_{ij}o_{ij}$, $\alpha_{34} = 1$, and $\alpha_{36} = 0$ while the other α's remain unchanged. Basically, the circulation system allows one to avoid the "obtain" process unless availability is assured. The overall probability of success does not change, but the average time to determine a request cannot be filled is decreased.

Now, consider what happens if we have network location information but not availability information either on a network or local basis. If the location information provides the call number or some other appropriate key, then $\alpha_{13} = 1$, $\alpha_{34} = a_{ij}$, and $\alpha_{36} = 1-a_{ij}$ while the remaining α's are zero. However, if the call number or equivalent is not available, $\alpha_{12} = 1$, $\alpha_{13} = 0$, and $\alpha_{23} = 1$ while the remaining α's are unchanged. In other words, without a call number or equivalent, one still must search the catalog.

If we couple network location information with a local circulation system, then if the call number or equivalent is available, $\alpha_{13} = a_{ij}$, $\alpha_{16} = 1-a_{ij}$, and $\alpha_{34} = 1$ while the remaining α's are zero. On the other hand, if call number or equivalent is not available, $\alpha_{12} = 1$, $\alpha_{13} = 0$, $\alpha_{16} = 0$, $\alpha_{23} = a_{ij}$, and $\alpha_{26} = 1-a_{ij}$ while the remaining α's are unchanged.

Finally, if we have network location information and the availability information provided by a network of circulation systems then, $\alpha_{13} = 1$ and $\alpha_{34} = 1$ while the remaining α's are zero.

Summarizing, we are considering the following alternatives.

1. Conventional network without location and availability information.
2. Local availability information provided by a local computerized circulation system.

3. Network location information with appropriate search key.*
4. Network location information without appropriate search key.
5. Network location information and local availability information with appropriate search key.
6. Network location information and local availability information without appropriate search key.
7. Network location information and network availability information.

The transition probabilities for the seven alternatives are summarized in Table I.

Thus, we have described how the various alternatives affect the flow of requests within resource libraries. In general, more technology allows one to avoid processes and thereby save processing time and costs. The next step in our discussion is that of determining how the alternatives will impact request routing among libraries. This will be discussed in the next section.

Before proceeding to the next section and our routing analysis, let us discuss briefly another alternative computer technology, namely complete computerization of request routing. In such a system, the requesting library would input a request via an in-house computer terminal. The computer would automatically determine whether or not the request could be satisfied, determine the fastest way to get the desired item to the requestor, and give immediate feedback to the requestor concerning the status of his request. It would also maintain request processing loads throughout the network, perform various accounting duties, etc.

* By search key, we mean information that allows one to avoid the card catalog and go directly to the shelf list and/or automated circulation system.

ALTERNATIVE	TRANSITION PROBABILITIES						
	α_{12}	α_{13}	α_{16}	α_{23}	α_{26}	α_{34}	α_{36}
1	1	0	0	o_{ij}	$1-o_{ij}$	a_{ij}	$1-a_{ij}$
2	1	0	0	$a_{ij}o_{ij}$	$1-a_{ij}o_{ij}$	1	0
3	0	1	0	0	0	a_{ij}	$1-a_{ij}$
4	1	0	0	1	0	a_{ij}	$1-a_{ij}$
5	0	a_{ij}	$1-a_{ij}$	0	0	1	0
6	1	0	0	a_{ij}	$1-a_{ij}$	1	0
7	0	1	0	0	0	1	0

TABLE I: TRANSITION PROBABILITIES FOR THE SEVEN ALTERNATIVE IMPLEMENTATIONS OF COMPUTER TECHNOLOGY

We will save further discussion of this interesting idea until later in our report. At that point, we will be able to discuss computerized networks with a perspective for the results obtained for the other alternatives.

ANALYSIS

In this section, we will derive the equations necessary for predicting the impact of the seven alternatives on network performance (i.e., probability of success, average time to satisfy a request, total costs, and unit costs). A portion of this analysis duplicates that presented in Project Report No. 2. It is included here for completeness.

As usual, our description of the network starts with defining the demands on the network. Define λ_{jk}, $j = 1,2,\ldots, M$; $k = 1,2,\ldots, L$ as the <u>average</u> number of requests per day (or any other convenient unit of time) generated* by System k in request class j. We will refer to this demand as type jk demand.

If we know the probability of satisfying type jk demand (denoted by p_{jk}) and the average time to satisfy type jk demand (denoted by w_{jk}) and the average unit cost to satisfy type jk demand (denoted by c_{jk}), then network performance could be calculated using

$$P = \sum_{j=1}^{M} \sum_{k=1}^{L} \lambda_{jk} \, p_{jk} / \Lambda \tag{1}$$

$$W = \sum_{j=1}^{M} \sum_{k=1}^{L} \lambda_{jk} \, p_{jk} \, w_{jk} / P\Lambda \tag{2}$$

$$C = \sum_{j=1}^{M} \sum_{k=1}^{L} \lambda_{jk} \, p_{jk} \, c_{jk} / P\Lambda \tag{3}$$

$$\Lambda = \sum_{j=1}^{M} \sum_{k=1}^{L} \lambda_{jk} \tag{4}$$

---

* Requests sent to the Center level of the network.

where P = probability of satisfying a request,

W = average time to satisfy a request,

C = average unit cost to satisfy a request,

Λ = total average demand on the network.

Thus, our problem is now reduced to calculating p_{jk}, w_{jk}, and c_{jk}. Define $\lambda_{ijk\ell}$ as that portion of λ_{jk} that enters Center i at the ℓth stage of its referral route. Then, we can calculate p_{jk}, w_{jk}, and c_{jk} using

$$p_{jk} = \sum_{i=1}^{N} \sum_{\ell=1}^{n_{jk}} \lambda_{ijk\ell}\, p_{ijk\ell}/\lambda_{jk} \tag{5}$$

$$w_{jk} = \sum_{i=1}^{N} \sum_{\ell=1}^{n_{jk}} \lambda_{ijk\ell}\, p_{ijk\ell}\, w_{ijk\ell}/p_{jk}\, \lambda_{jk} \tag{6}$$

$$c_{jk} = \sum_{i=1}^{N} \sum_{\ell=1}^{n_{jk}} \lambda_{ijk\ell}\, p_{ijk\ell}\, c_{ijk\ell}/p_{jk}\, \lambda_{jk} \tag{7}$$

where N = number of Centers,

n_{jk} = length of referral route for type jk demand,

$p_{ijk\ell}$ = probability of satisfying type jk demand at Center i at the ℓth stage of referral,

$w_{ijk\ell}$ = average time to satisfy a request (cumulative and including delivery) if it is satisfied at Center i at the ℓth stage of referral,

$c_{ijk\ell}$ = average unit cost to satisfy a request (cumulative) if it is satisfied at Center i at the ℓth stage of referral.

Equation 7 must be modified to include the cost of unsatisfied requests in the overall unit cost of satisfaction.

$$c_{jk} = \left(\sum_{i=1}^{N} \sum_{\ell=1}^{n_{jk}} \lambda_{ijk\ell}\, p_{ijk\ell}\, c_{ijk\ell} + \lambda_{jk}(1-p_{jk})\tilde{c}_{jk} \right) / p_{jk}\, \lambda_{jk} \qquad (8)$$

where $\tilde{c}_{jk}$ = average unit cost for type jk demand that is not satisfied.

Thus, the problem is now reduced to calculating $\lambda_{ijk\ell}$, $p_{ijk\ell}$, $w_{ijk\ell}$, $c_{ijk\ell}$, and $\tilde{c}_{jk}$. To pursue this calculation, we will partition the seven alternatives into three groups. Group A will contain alternatives 1 and 2. Group B will contain alternatives 3 through 6. Group C will contain alternative 7. These groupings represent different types of routing policies and thus, we develop different equations for each group.

Before discussing the equations for each group, we will consider routing policies. In Project Report No. 3, we defined the value of a Center to be probability of success divided by the average delay. In this report, we will continue with this somewhat arbitrary choice and assume that the best routing policy for type jk demand is to refer it to Centers of decreasing value. Thus, the first Center in its route will be that with highest value; the second Center in its route will be that with next highest value; etc. Defining $p_{ij\ell}$ as the probability of satisfying type jk demand at Center i given that the demand is at its ℓth stage of referral then,

$$V_{ij\ell} = \frac{p_{ij\ell}}{p_{ij\ell}(\hat{w}_{ij\ell} + t_{ik}) + (1 - p_{ij\ell})\,\tilde{w}_{ij\ell}} \tag{9}$$

where $V_{ij\ell}$ = value of Center i as the ℓth referral Center for type jk demand,

$\hat{w}_{ij\ell}$ = average processing time at Center i for satisfied type jk demand at the ℓth stage of referral,

$\tilde{w}_{ij\ell}$ = average processing time at Center i for unsatisfied type jk demand at the ℓth stage of referral,

t_{ik} = average delivery time from Center i to System k.

Given $V_{ij\ell}$, one can determine a routing vector $r_{jk\ell}$, $j = 1,2,\ldots, M$; $k = 1,2,\ldots, L$; $\ell = 1,2,\ldots, n_{jk}$ whose members denote the series of Centers to which a request will be routed until it is satisfied or reaches the end of its route.

Analysis for Group A:

The alternatives in Group A (numbers 1 and 2) represent the situations analyzed in earlier reports. For this group, we find that*

$$\lambda(r_{jk\ell},j,k,\ell) = \prod_{m=1}^{\ell-1} [1 - p(r_{jkm},j,k,m)]\,\lambda_{jk} \tag{10}$$

$$p(r_{jk\ell},j,k,\ell) = o(r_{jk\ell},j,\ell)\; a(r_{jk\ell},j,\ell) \tag{11}$$

$$w(r_{jk\ell},j,k,\ell) = \sum_{m=1}^{\ell-1} \tilde{w}(r_{jkm},j,m) + \hat{w}(r_{jk\ell},j,\ell) + t(r_{jk\ell},k) \tag{12}$$

---

* Subscripts are sometimes bracketed for clarity. Thus, $\lambda(i,j)$ and λ_{ij} are equivalent.

$$c(r_{jk\ell},j,k,\ell) = \sum_{m=1}^{\ell-1} \tilde{c}(r_{jkm}) + \hat{c}(r_{jk\ell}) \tag{13}$$

$$\tilde{c}_{jk} = \sum_{m=1}^{n_{jk}} \tilde{c}(r_{jkm}) \tag{14}$$

where $o_{ij\ell}$ = probability that Center i will own an item in request class j given that the request is at its ℓth stage of referral,

$a_{ij\ell}$ = probability that an item in request class j will be available given that it is owned by Center i and that the request is at its ℓth stage of referral,

$\hat{c}_i$ = cost of successfully processing a request at Center i,

$\tilde{c}_i$ = cost of unsuccessfully processing a request at Center i.

Analysis for Group B:

The alternatives in Group B (numbers 3 through 6) represent situations somewhat different from those analyzed in earlier reports. The difference occurs in the utilization of the routing vector. Given a type jk request, we look at $r_{jk\ell}$ and decide how to route that request. Initially, we would plan to start the request at Center r_{jk1}. Using the network location information available with the alternatives in Group B, we would check to see if Center r_{jk1} owns the desired item. We would find that the Center would own $o(r_{jk1},j,1)$ of the items checked. Thus,

$$\lambda(r_{jk1},j,k,1) = o(r_{jk1},j,1)\ \lambda_{jk} \quad . \tag{15}$$

Center r_{jk2} would own $o(r_{jk2},j,2)$* of the items not owned by Center r_{jk1} and thus,

$$\lambda(r_{jk2},j,k,1) = o(r_{jk2},j,2)[1-o(r_{jk1},j,1)]\ \lambda_{jk} \quad . \tag{16}$$

In general,

$$\lambda(r_{jk\ell},j,k,1) = o(r_{jk\ell},j,\ell) \prod_{m=1}^{\ell-1} [1-o(r_{jkm},j,m)]\ \lambda_{jk} \quad . \tag{17}$$

Now, considering the 2nd stage of referral, we note immediately that

$$\lambda(r_{jk1},j,k,2) = o \tag{18}$$

which reflects the fact that Center r_{jk1} had the opportunity to receive all of λ_{jk} at the 1st stage of referral and thus, it would be senseless to refer back to r_{jk1} any of the demand not satisfied by the other Centers.

Center r_{jk2} can be referred any demand which r_{jk1} could not satisfy due to unavailability. Thus, we obtain

$$\lambda(r_{jk2},j,k,2) = o(r_{jk2},j,2)[1-a(r_{jk1},j,1)]\ \lambda(r_{jk1},j,k,1) \quad . \tag{19}$$

In general, we find that Center $r_{jk\ell}$ can be referred any demand not satisfied by r_{jk1}, r_{jk2},..., $r(j,k,\ell-1)$. Therefore,

$$\lambda(r_{jk\ell},j,k,2) = o(r_{jk\ell},j,\ell) \sum_{m=1}^{\ell-1} \left\{ \prod_{n=m+1}^{\ell-1} [1-o(r_{jkn},j,n)] \right\} [1-a(r_{jkm},j,m)] \times \lambda(r_{jkm},j,k,1) \quad . \tag{20}$$

---

* The 2 here does not denote actual referral. Instead, it reflects the fact that Center r_{jk2} may be less likely to own a request that is already found to be unowned by Center r_{jk1}.

For the ℓth referral, we obtain

$$\lambda(r_{jk\ell},j,k,\ell) = o(r_{jk\ell},j,\ell) \sum_{m=1}^{\ell-1} \left\{ \prod_{n=m+1}^{\ell-1} [1-o(r_{jkn},j,n)] \right\} [1-a(r_{jkm},j,m)] \times \lambda(r_{jkm},j,k,\ell-1) \quad (21)$$

Given that a request at its ℓth stage of referral is processed by Center $r_{jk\ell}$, the probability of success is defined by

$$p(r_{jk\ell},j,k,\ell) = a(r_{jk\ell},j,\ell) \quad . \quad (22)$$

If a request is satisfied by Center $r_{jk\ell}$ at its ℓth stage of referral, the average time to satisfy the request is given by

$$w(r_{jk\ell},j,k,\ell) = \frac{o(r_{jk\ell},j,\ell)}{\lambda(r_{jk\ell},j,k,\ell)} \sum_{m=1}^{\ell-1} \left\{ \prod_{n=m+1}^{\ell-1} [1-o(r_{jkn},j,n) \right\} [1-a(r_{jkm},j,m)] \times \lambda(r_{jkm},j,k,\ell-1)\, \tilde{w}(r_{jkm},j,m,\ell-1) + \hat{w}(r_{jk\ell},j,\ell) + t(r_{jk\ell},k) \quad (23)$$

where $\tilde{w}(r_{jkm},j,m,\ell-1)$ is the cumulative average time to be unsuccessfully processed at the first ℓ-1 stages of the referral route and is given by

$$\tilde{w}(r_{jk\ell},j,k,\ell-1) = \frac{o(r_{jk\ell},j,\ell-1)}{\lambda(r_{jk\ell},j,k,\ell-1)} \sum_{m=1}^{\ell-2} \left\{ \prod_{n=m+1}^{\ell-2} [1-o(r_{jkn},j,n)] \right\} [1-a(r_{jkm},j,m)] \times \lambda(r_{jkm},j,k,\ell-2)\, \tilde{w}(r_{jkm},j,k,\ell-2) \quad (24)$$

where $\tilde{w}(r_{jkm},j,m,o)$ is zero.

The equations for $c(r_{jk\ell},j,k,\ell)$ are identical with $\tilde{c}$ and $\hat{c}$ substituted appropriately and t_{ik} deleted. $\tilde{c}_{jk}$ is given by

$$\tilde{c}_{jk} = \sum_{\ell=1}^{N} \sum_{m=1}^{n_{jk}} \lambda(r_{jk\ell},j,k,m)[1-p(r_{jk\ell},j,k,m)] \prod_{n=\ell+1}^{N} [1-o(r_{jkn},j,n)] \chi$$

$$\tilde{c}(r_{jk\ell},j,k,m)/\lambda_{jk}(1-p_{jk}) \tag{25}$$

Analysis for Group C:

The alternative in Group C (number 7) represents the situation where the request is only sent to a Center where it will be satisfied. Thus, the request is sent to the first Center in the route that both owns the desired item and has it available. There is only 1 stage of referral. Thus,

$$\lambda(r_{jk\ell},j,k,1) = o(r_{jk\ell},j,\ell)\ a(r_{jk\ell},j,\ell) \prod_{m=1}^{\ell-1} [1-o(r_{jkm},j,m)\ a(r_{jkm},j,m)]\ \lambda_{jk},$$

$$p(r_{jk\ell},j,k,1) = 1, \tag{26}$$

$$w(r_{jk\ell},j,k,1) = \hat{w}(r_{jk\ell},j,\ell) + t(r_{jk\ell},k), \tag{27}$$

$$c(r_{jk\ell},j,k,1) = \hat{c}(r_{jk\ell}) \quad . \tag{28}$$

and $\tilde{c}_{jk} = o$.

The calculation of $\hat{w}_{ij\ell}$, $\tilde{w}_{ij\ell}$, $\hat{c}_i$, and $\tilde{c}_i$ is straightforward and accomplished by using Figure 1 and Table I and simply noting how successful and unsuccessful requests pass through the processes. Knowing the average time required for each process and the cost associated with each process, one can easily tabulate the desired estimates.

RESULTS AND CONCLUSIONS

Tables XA, XIII, XIV, XV, and XVI of Project Report No. 3 define all the input data necessary to the equations derived in the previous section. Now, let us consider how network performance is affected by alternative implementations of computer technology. The results appear in Table II.

The range of the results is very interesting. With alternative 1, a probability of success of 0.938 can be achieved at a yearly average cost of $628,356 and with an average time to satisfy a request of 10.3 days. On the other hand, alternative 7 yields the same probability of success with a yearly average cost of $227,335 and with an average time to satisfy a request of 5.5 days. This is quite an impressive improvement in performance. Let us now consider how performance incrementally improves as we proceed through all the alternatives from 1 to 7.

Recall that alternative 1 represents the situation with no location and availability information. This is not the status quo in Illinois as there are several filmed catalogs available that yield location information. Nevertheless, alternative 1 represents a baseline against which to make comparisons. Alternative 2 represents the addition of local automated circulation systems (e.g., CLSI). The main benefit to ILL operations realized by implementing the alternative is the avoiding of the "obtain" process when an item is owned but unavailable. This should reduce average time to satisfy a request. However, the results in Table II indicate no improvement and this is due to the fact that the data set we employed indicates that the obtain process consumes very little time and

ALT.	REFLS.	PROB.	DELAY	COST/REQ.	COST/DAY	COST/YR.
1	0	67.5	7.5	2.97	1728	431948
1	1	88.1	9.3	3.00	2273	568151
1	2	92.1	9.9	3.06	2426	606423
1	3	93.8	10.3	3.11	2513	628356
2	0	67.5	7.5	2.97	1728	431948
2	1	88.1	9.3	3.00	2273	568151
2	2	92.1	9.9	3.06	2426	606423
2	3	93.8	10.3	3.11	2513	628356
3	0	86.0	5.6	1.14	844	211041
3	1	93.2	6.3	1.15	922	230497
3	2	93.8	6.4	1.15	927	231866
3	3	93.8	6.4	1.15	928	231942
4	0	85.5	7.3	2.47	1815	453830
4	1	93.2	8.1	2.50	2001	500283
4	2	93.8	8.2	2.50	2018	504425
4	3	93.8	8.3	2.50	2019	504747
5	0	86.0	5.6	1.14	843	210867
5	1	93.2	6.3	1.15	922	230409
5	2	93.8	6.4	1.15	927	231779
5	3	93.8	6.4	1.15	927	231854
6	0	85.5	7.3	2.47	1815	453830
6	1	93.2	8.1	2.50	2001	500283
6	2	93.8	8.2	2.50	2018	504425
6	3	93.8	8.2	2.50	2019	504747
7	0	93.8	5.5	1.13	909	227335

TABLE II: IMPACT OF ALTERNATIVE TECHNOLOGIES ON NETWORK PERFORMANCE thus, by avoiding this process, very little time is saved. In fact, we find it difficult to accept that the obtain process consumes so little time. (See pp. 31-32 of Project Report No. 3 for a discussion on this point.) More data should be gathered, especially at UOI with its geographically disperse campus.

Alternative 3 represents the addition of network location information without availability information. Also, this alternative assumes that the location information includes an appropriate search key (e.g., call number) for locating the item once the request is received by a specific Center. Filmed catalogs have this information but cataloging networks such as OCLC may not necessarily have the call number for every library holding a particular item. For example, a cataloging network may tell you that UOI owns a particular item, but may not be able to give the Dewey call number used at UOI for that item. Alternative 4 represents the situation when an appropriate search key is not available. Much of the cost savings due to having location information is lost when an appropriate search key is not available. To be very specific, comparing alternatives 3 and 4 to alternative 1, we should be willing to pay approximately $2.00 per request for location information with search key (i.e., comparing alternative 3 to 1) but only approximately $0.50 per request for location information without search key (i.e., comparing alternative 4 to 1). It is interesting to note that OCLC has recently announced* their plans to offer an ILL option for $0.42 per request per referral. If they provide appropriate search keys for all of the Centers, this would be an attractive price for up to 3 referrals (i.e., processing at 4 Centers). On the other

---

* Advanced Technology Libraries 5:4 (April 1976) p.2.

hand, without appropriate search keys, this would only be an acceptable price for processing at a single Center (i.e., a direct request). Of course, for requests sent outside of ILLINET, reimbursement for processing is no longer a factor and thus, cost-wise, the $0.42 is unattractive unless balanced against other performance improvements.

Another comparison is that of OCLC versus filmed catalogs. If one were already using OCLC for cataloging and if appropriate search keys were available, then it would be hard to justify filmed catalogs on other than a retrospective basis. Note that this conclusion does not depend on how much of the network's holdings are in the OCLC data base. As long as ILL charges are only based on requests sent through the network and not on searches of the data base, then one would only pay for successful retrieval of location information. Thus, even though several filmed catalogs already exist in Illinois, the location information available via OCLC can still be economically justified. Of course, this depends on being able to write off terminal costs, etc. against cataloging activities. On the other hand, if OCLC was being utilized solely for ILL or if there were substantial data base search charges, then justification of using OCLC would depend on what portion of the network's holdings were in the data base.

Alternatives 5 and 6 represent the addition of local availability information to the network location information of alternatives 3 and 4. As with alternative 2, the chief benefit of local availability information should be time savings. However, this savings is not realized because our data says that the "obtain" process only requires minimal time. Again, we want to stress that more data is necessary for studying this intuitively unappealing conclusion.

Alternative 7 represents a situation with network location and network availability information. We assume that an appropriate search key for access of the network availability information exists. Otherwise, network availability information would be of little use. The benefit of this alternative over alternative 5 is a time savings due to always sending a request to where it will be satisfied. The relatively small time savings of approximately 1 day is due to ISL's dominance of the network. The cost savings noted between these two alternatives is due to different routes being used, based on equation 9.* This difference is marginal and dependent on the specific libraries in a network. Thus, the cost savings is not a general result due to implementation of alternative 7.

We noted earlier in this report, that another alternative is complete computerization of the network. With one exception, the performance benefits of this alternative would not significantly surpass those available with alternative 7. The exception is in the area of managing the processing load at each Center. Due to a lack of data, our analyses here have not considered how processing load affects request waiting lines (queues) and hence processing times. A computerized network would allow instantaneous load management that would avoid this problem. Of course, the computer could also collect data that is necessary to assessing network performance, perform accounting duties, and manage network performance so as to assure equitable service throughout the network.

---

* Several of the minor differences in Table II are merely due to routing differences that result when equation 9 is employed. These routing differences cannot be intrinsically attributed to the alternative technologies and thus, these minor differences only reflect our choice of routing criterion.

What can we conclude from our analyses? First, location information is very valuable and filmed catalogs may be worth several hundred thousand dollars per year to ILLINET. If OCLC provides appropriate search keys for local retrieval of the desired item, its price of $0.42 per request per referral is attractive. Without the appropriate search key, filmed catalogs may be a better investment. (Naturally, this assumes that filmed catalogs and subsequent updates can be produced with the cost savings provided by having location information.) Local availability information appears to be of little value regardless of whether or not location information is accessible. However, we feel this conclusion to be an artifact of the data set employed. Thus, we urge that appropriate data be collected. Network availability information reduces average time to satisfy a request since only a single Center must process the request.

As a final note, we want to caution the reader that the predicted cost savings discussed in this report are dependent on the reimbursement structure employed. The substantial savings noted with network location information are due to avoiding the "search" process at the Centers. However, without network availability information, Centers will still process requests that they cannot satisfy. Since search is avoided, the current reimbursement structure would pay them nothing when they unsuccessfully process requests. It is doubtful that this would be a popular situation. Thus, an alternative reimbursement structure might be necessary. The methodology presented in this report could predict the impact of alternative reimbursement schemes without any forseeable software modifications.