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This paper is an explication of the concept of a network of consultants to help people obtain answers to day-to-day questions for which answers are known. Each member of such a network is viewed to have three capabilities: 1)answering questions directly from his own memory, 2)answering questions with the aid of library resources, and 3)referring the question to a member of the same network or to an expert outside it. Conditions are derived which involve each member's ability to choose appropriately among the three alternatives. If he judges correctly concerning when and where to refer a question, such a network, suitable organized, has greater net utility than does a reference librarian by himself. Mathematical models are used to formulate and analyze designs for the referential consulting function. It is argued that the existence of such a network makes possible a much broader range of information service to the community than is afforded by traditional reference librarianship. (Author/JB)

Referential Consulting Networks

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1. Introduction

Who has not discovered treasure in a library? An exquisite, bewildering variety of treasures. A few come in the form of answers to riddles or urgent questions, explicitly stated or covert. Most forms take the shape of books, and traditional libraries as well as their users value the physical form alongside the content it embodies. But how can we better think of the use of libraries as analagous to treasure hunting? We discuss this question by helping to explicate "reference service" as a theoretical concept, and by seeking conditions for excellence of such service. Few of us expect libraries to help solve our most common or most urgent day to day problems. Seldom does a voter who just moved into a community, for example, think of the local librarian as his most promising source of help in evaluating the candidates or the issues in an impending election.[1] But, it is conceivable that the local reference librarian -- or rather his modernized counterpart, the community's professional information-please officer, for whose existence we argue in this paper -- could help the newcomer, perhaps better than any other source to which he, on his own, would think to turn. Certainly the library contains copies

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[1]For some typical questions with which libraries deal see the excellent compilation: Case Studies in Reference Work by Grogan (7).

of at least the local newspaper which might have sketched the qualifications of the candidates and summarized the pros and cons of the issues; it might also contain more detailed readings on the issues as well as biographies.

The traditional definition of a library is: a "collection of books organized for use". But the word, "use", is explicated no further. To maintain a collection organized for use, the library performs three traditional functions: (a) book selection, (b) bibliographic control, (c) reference.

It is also traditional to complain that library resources are under-utilized. De Solo Pool (17) estimated that less than one-quarter of Americans, when in need of information, regularly use libraries. Of these regular university and college library users, the majority do known-item searches, and less than 30% do subject searches, according to Brooks and Kilgour (2), Lipetz and Stangl (13) Palmer (15), and a current catalog use study by us (21). A recent study directed by Swanson (20) also showed that experimental subjects recall the title or author of a book with sufficient accuracy to locate the book through the catalog only one quarter of the time. Finally, even if a book is located in the catalog -- in either a known-item or a subject search -- it is likely to be found in the stacks in slightly less than half of the cases for a number of large libraries where such studies were made.

It has been said that library sources are under-utilized because potential users have dismal expectations. These figures do little to help those who argue that such expectations are unjustified. If we use libraries rarely to acquire knowledge, understanding or wisdom when we can't specify a book likely to help us, then we are under-utilizing library resources even more than is traditionally supposed.

These depressed conditions may be due to an overly narrow and outdated conception of libraries and librarianship rather than to poor performance of the three library functions. Shera and Egan (5) challenged the traditional concept of a library when they proposed that its function should be "to maximize the effective social utilization of the graphic records of civilization". This redefinition is a vast step forward, because it did not confine the librarians' responsibility to books, nor to a specific collection usually delimited by funds and space. Above all, it replaced the vague term "use" by the more meaningful term "maximize the effective social utilization".

The Shera-Egan proposal, however, implies that if a member of the U.S. Congress acts on an important social issue on the basis of wrong or missing knowledge when the correct information exists in the Library of Congress, then the Librarian of Congress is responsible. He should have seen to it that the legislator was given the option of using, not using, or misusing, relevant knowledge in the Library.

But the Librarian can hardly be expected to share the entire responsibility for the legislator's misuse or failure to use such knowledge. Misuse of relevant knowledge does not maximize its "effective social utilization".[2]

[2] For example, when Stalin ignored the well documented, encyclopedic compilation of Soviet intelligence by Richard Sorge, which showed that the Germans would attack Russia on June 22, 1941, Sorge was in no way to blame for such minimizing of the effective social utilization of graphic records.

The Librarian (of Congress, or Sorge, in the above examples) is only partially responsible. Perhaps the Shera-Egan definition should be revised to: "to maximize the greatest potentially attainable effective and efficient social utilization of documented knowledge." Note that we also substituted the more abstract term "documented knowledge" for the "graphic records of civilization", to include non-graphic embodiments of documented -- i.e., validated -- truths, such as magnetic tape recordings. Note also the insertion of "and efficient" to suggest that this is to be done with a reasonable or minimum expenditure of necessary resources; in particular, the cost of information overload on the user due to lack of fine selectivity is to be kept within bounds.

How can librarianship change to fulfill most effectively the new demands of such a revised definition? Some thought has already been given to this question. At a conference on reference and information services held at Columbia University in 1966, Kilgour (9) stressed the need for a more intellectual approach to librarianship. The development of the "knowledge industry" has placed libraries in a much more central and responsible position in our society, which demands recognition of new, more viable techniques in librarianship.

Because of these increased responsibilities to the community of users, the reference function has become especially important. Thus far, however, reference librarians have no established definition of the scope and method of their work.* Wynar has defined reference

*This is not meant to imply that there are no definitions at all. The ALA Glossary, for example, has defined reference work as "that phase of library work which is directly concerned with assistance to the readers in securing information and in using the resources of the library in study and research."

service as "any activity related to providing information as well as guidance and instruction in the use of library resources (a necessary compromise)".(25) Unless one recognizes, however, that 'information' and 'library resources' have become vastly broader in scope, such a definition could easily be applied to a very conservative exercise of the reference function. The vastness and variety of resources available to the reference librarian make necessary the development and use of a real information and referral network if libraries are to achieve "the greatest potentially attainable effective social utilization of documented knowledge".

In this paper we stress such an expanded scope and depth for reference librarianship. If mathematical library scientists can be stimulated to explore and develop the various lines of investigations opened up by the models sketched later in this paper, perhaps the concept of indirect referral will come to be recognized as a very important part of any good theory of reference service.

2. The Reference Function

The concept of "reference" is probably the most basic in library science. Although the word "refer" has several meanings (e.g., the librarian referred him to an encyclopedia; or to a consultant; the book referred to baseball scores; the user referred to an encyclopedia), they all involve the action of pointing, directing, "passing the buck".

In order to perform this referral function well, the reference librarian must be a generalist. While he does not have to know where to look up the latest and most reliable measurement of the velocity of light, he should at least know whom to ask, or whom to ask for a name of someone to ask. Like an executive, he needs more to know to which source to assign the responsibility for solving a problem than to solve the problem himself.

Consider the following sample of possible information needs on the part of average people in their daily lives, at work or at home.

P1. What is the address of the Bolger Laboratory, in the vicinity of Boston? (The client may be a doctor and on questioning reveal that Bolger is a drug testing lab.).

P2. A herpaterium attendant is showing symptoms of snake poisoning, though he hasn't recently been bitten.[3] Has anyone ever published reports of delayed snake poisoning? (The client may be a local physician or the afflicted patient; he might even settle for unpublished reports or the names of experts, or the names of people who have encountered this).

P3. We just moved into the city of Jonesville which has no local hospital, and our child seems to have heart trouble from eating too much animal fat. What kind of physician should we call? And how can I get reliable help in selecting one? (The client might wish a "non-obsolete cardiologist, hematologist or internist", though he may not realize how to ask for or spot one.)

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[3] This example is due to D. Dennis, then head of the Health Sciences Library at the University of Michigan, now at the National Library of Medicine (private communication). This request was forwarded from a small town to the regional Medlars post in Ann Arbor, thence to NLM in Washington. The Medlars search revealed one relevant paper which was supplied a day later (rather than the usual 2 weeks) because of possible urgency of the case.

P4. I need a light, strong, rust-resistant material for a toy I wish to produce and market. What should I consider? (The client may be happy to learn of the existence of a materials information center, or even of a directory which informs him of its existence).

P5. Mr. Green is being considered for a very responsible public position, and I must decide whether or not to endorse this appointment. Where can I get pertinent information about him?

P6. Gross sales and morale in our company have been declining steadily since last January. What should we do?

P7. Lately everyone seems to be taking advantage of me and I feel very uncomfortable with other people. It has reached the point that I can't even show my face to my fellow workers anymore. I need help desperately.

P8. Our university is considering increasing its investment in computers to $10 million/year by 1970. How can we make sure of getting an optimal return on this investment, especially so as not to aggravate our key problems?

P9. What would be the economic consequences of establishing and enforcing national standards in the metric system, to be in effect by 1975?

P10. How have the attitudes of Southern whites toward integration changed from 1900 to 1968.

Consider next the following sample of "answers" for which the questions may have to be found, sought out, motivated:

A1. A new serum which is extremely effective against many kinds of snake poisoning was recently tested by the Bolger Labs. (The author of P2 may be interested).

A2. Dr. Jones, who has been practicing cardiology in Jonesville for the past 30 years, was found guilty in a malpractice suit in 1950; after one year in jail, he returned to his practice. (The author of P3 may be interested).

A3. Action is urgently needed on the long-delayed discussions about U.S. arms aid for Israel.

A4. The second law of thermodynamics implies the impossibility of perpetual motion machines. (The inventor of a perpetual motion machine ought to be interested).

A5. Task forces in which the members' personalities are most alike on their need to give and get affection have higher morale and productivity than do task forces in which the members' personalities are dissimilar in this respect, regardless of other personality factors. (The author of P6 may be interested).

Statements such as A1-A5 usually appear in newspapers and journals. Libraries, at best, publish a periodic accesssion list of book titles, and regard anything beyond this as the responsibility of information centers.[4]

Few users would think of using a library for an answer to P1,

[4] Eloquent refutations of this viewpoint have been made by Lorenz (14) Freiser (6), and Rees (18).

when they could ask a telephone operator or a colleague to help them. While many librarians may not consider themselves responsible for helping a user with such a problem, most librarians could with great facility find the answers while the user is still on the telephone; if they could, they would probably be eager to do so.

No one in the public library of the small town receiving query P2 may have the materials, the time or the expertise to do the search, but he should give the user the telephone number of, or better yet, switch the call directly to the nearest MEDLARS search center.

There is hardly any source to which a person can turn with P3 except simply picking a hospital or physician from the classified telephone directory. A person with problems like P4 or P6 would normally seek the services of a consultant rather than a librarian; for P4 a consultant might consult literature and look up a material with specified properties, though some librarians could do this, too. If he cannot handle P4, and certainly for P6, the information officer could reasonably be expected to refer the client to an appropriate consultant.

A personnel investigation such as called for in P5 is usually started by personal contacts who know people who know people ..., etc. The librarian does not now expect, or is not now expected, to contribute vitally to such an investigation, but his 1980 counterpart will have the opportunity to do so.[5]

[5] A unique, early experiement in using libraries as community information centers is the Sheffield Free Public Library System, Sheffield, England. For details see (19).

Suppose that, in addition to "socially acceptable or neutral" questions like P1 - P10, the information officer receives questions that lead him to suspect antisocial, criminal, revolutionary or otherwise destructive intent by the questioner. Of course, the information officer, as an individual, employs his personal value system in judging these questions and interests. If his value system is not consistent with that of his supporters, and the general social group in which it is embedded he is likely to be replaced, or the information service will not remain viable. Conflicting social groups might develop competitive information systems, and through a natural system of checks and balances a larger information system emerges.

This important question requires separate discussion, which was already partly begun by H. G. Wells (23). It should be kept in mind that, in general, there exists more than one referential consulting network. This gives a user options about where to turn first.

A person who can give users with <u>any</u> question resembling the above minute sample some useful first lead toward an answer would be a most important professional in the community. Is it suggested that librarians of the future be expected to discharge these great responsibilities? Yes, though they should perhaps, no longer be called librarians to dispel any association with users' and librarians' own past images of their profession. They might be called "information officers", "general community advisors" or something like that. To discharge such responsibilities at a high level and standard, they would have to be selected and educated to possess adequate qualifications, mainly an advanced liberal arts background; they would have prestige and pay scales comparable to those of other professional consultants in law, medicine, engineering, etc.

Just what, however, is the nature of this referential consulting task? How can its performance be evaluated? What resources are necessary to perform it well? In what follows we try to answer the first two questions, deferring the last to other papers.

Let us simplify our discussion by restricting the referential consultant's role entirely to question-answering. This includes question-negotiation. But it postpones for another study the even more significant role of helping selected people seek the questions to which he can provide answers. The referential consultant, henceforth denoted by R, can draw on three main resources in answering questions:

(I) his own understanding and memory

(II) his auxiliary memories and means of access to them

(III) his colleagues who are themselves referential consultants.

To fix ideas, imagine a community, such as all residents of a township on a given date, from which arises a stream of questions of unlimited variety. Select any question from this stream at random. Call it q. Suppose that it is forwarded to R. If q falls into R's expertise, he may try to answer it directly, drawing on resource (I). In this regard R acts not only as a <u>referential</u> consultant but as an expert consultant. In other words, every R is also an expert consultant to some degree for some class of questions.[6]

If R cannot rely on resource (I) alone but believes that he can find (or check) the answer with the help of resource (II), he does so. By auxiliary memories we mean an abstraction of the resources consisting of what is now his filing cabinet, a collection of reference books at his fingertips, his personal library including old notes, address books, all kinds of directories, tests, papers, etc.; also included is the nearest non-personal library, such as the departmental library (in a university, research center or other organization) located within 100 yards of his office; the next larger "regional" library (of which his departmental library may be a branch). Indeed the entire international network of library resources to which he has access (at least through conventional inter-library loans) is indirectly part of the resource (II). For any particular R, the Library of Congress, of course, can hardly be called his auxiliary memory; he shares it with millions of others. And we are justified in calling it an aid to memory only to the extent that he recalls enough of the title, author, or subject-headings of a book he remembers to contain the answer to q. In other words, viewing the use of a library as an aid to memory is consonant with a large number of uses to which libraries are put: known-item searching for items other than those recommended by colleagues or cited in other documents. Even the latter

[6]Although the problem of expertise might raise several interesting questions, we do not stress it in this paper. We treat R as a specialist only secondarily.

can often be interpreted as an aid in recall. So, every R is to some degree also a reference librarian as well as a literature searcher/analyst for some class of questions. It is this use of resource (II) that we stress most in this paper.

If it takes R too long, too much effort, or if R judges it unlikely that he will answer q with the help of resources (I), or (II), he resorts to "buck-passing". This is most important. It is not meant to have any negative connotation this colloquialism may imply. It takes considerable wisdom by R to exercise good judgment about whether and just when he ought to refer the question to someone else.[7] Thus, every R is also to some degree a buck-passer for some class of questions.

We assume that no R engages in research. If the answer to q is "not known" either in the recorded literature or within the community of R's, then q may be referred to an outside community of researchers. By saying that the answer to q is knowr we mean that it can be looked up, recalled, retrieved -- that q has previously been answered -- and that it need not be deduced or inferred.

What about questions asking for advice, opinion, stimulation, for education, decisions, for service, like P6? Or questions revealing (or concealing) illness, confusion, ignorance, malice, need, like P7? Responses to such questions differ sharply from "answers" in the sense meant above. Let us suppose, as in the case of questions requiring research, that such questions are referred by any R in the community

[7]For more comments on the effectiveness of question referral, see (3).

of referential consultants to someone in an outside professional community of doctors, lawyers, teachers, ministers, public servants, social workers, businessmen, etc. The important qualification required of an R is the ability to recognize <u>when</u> to refer a question and good judgment about where to refer it.

This means that the referential consultant is a very responsible professional. Though he may also be a specialist he must be, first and foremost, a generalist. He should be broadly and deeply educated in "advanced liberal arts", experienced in and dedicated to public service with mature, sound judgment concerning the wise use of resources (I) - (III). He need not be a scholar, researcher, innovator, teacher, nor what is now a professional librarian. He would constitute a new breed of professional, a pillar of his community, a highly valued (and paid), esteemed and essential leader of that community.

3. A First Mathematical Model[8] for an Idealized Referential Consulting System: A Chain Organization

Consider a community of n referential consultants. Label them $R_1, R_2, \ldots, R_n$. Suppose that the randomly selected question q always

[8]We use the term "model" not to describe more simply an observed entity, nor to depict an ideal way of performing a function, but to formulate and analyze designs for the referential consulting function. The virtues and limitations of mathematical thinking are well known: clarity at the cost of oversimplification, insight at the price of exact applicability, stimulation for all kinds of further investigation, experimental and theoretical, in place of minutely cataloged observations and data describing existing reality. Theories can be better analyzed and compared if expressed mathematically, though existing mathematics imposes limitations on the complexity of theories. Sometimes mathematics is inappropriately used in a merely decorative manner. Candidly, we create and analyze models because it is exciting; models are the breeding ground of intellectual problems.

reaches R_1 first. This assumption is weakened in more refined models. To reduce verbiage, let K_i denote the event that R_i knows the answer to q, using resources (I) or (II). Let A_i denote the event that R_i produces an answer to q within a certain time after q reaches him, having used resources (I) or (II). Also, $\bar{K}_i$ and $\bar{A}_i$ stand, respectively for the events of R_i not knowing and not answering q.

Next, we characterize R_i by the following variables: a_i is the probability of K_i; $b_i = 1 - a_i = \text{Prob}(\bar{K}_i)$; p_i is the conditional probability of A_i given K_i, and

$$q_i = 1 - p_i = \text{Prob}(\bar{A}_i | K_i)$$
$$p'_i = \text{Prob}(\bar{A}_i | \bar{K}_i)$$
$$q'_i = \text{Prob}(\bar{A}_i | \bar{K}_i).$$

We characterize the system as follows: v is the utility of an acceptable answer to q, averaged over all q; c is the cost to the querist of an unacceptable* answer to q, averaged over all q; V is the total net utility of the system per question, averaged over all questions.

Assumption 1. $a_i = a + (i-1)e$, $i=1,...n$. If R_i does not answer q, he refers it to R_{i+1} for $i=1,...,n-1$.

Assumption 2. $p_i = p'_i = p$ for $i=1,...n$.

Assumption 3. The conditional events $A_1|K_1$, $A_2|K_2$, ... $A_n|K_n$ are statistally independent.

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*An unacceptable answer is one which is either false or insufficient. Answers which are made unacceptable due to extensive delay are not dealt with here.

The first assumption implies a linear chain organization shown in figure 1.

$q \longrightarrow \boxed{R_1} \rightarrow \boxed{R_2} \rightarrow \boxed{R_3} \longrightarrow \cdots \longrightarrow \boxed{R_n}$ Figure 1: A chain network

If R_1 "passes the buck", it is <u>only</u> to R_2, who is more likely to know the answer to q than is R_1 by an amount e. Similarly, R_2 passes the buck to R_3, and R_n, the smartest of the group, is at the end of the line.

Given:

	A_i	$\bar{A}_i$
K_i	p_i	$1-p_i$
$\bar{K}_i$	$1-p'_i$	p'_i

Figure 2: The Contingency Table
"Knowing" and "Responding" to Questions

The assumption is best seen in the contingency table of fig. 2. The top left cell is the event that R_i answers q {using resources (I) and (II)}, given that he "knows" the answer.[9] Its probability should be fairly high perhaps .90. The bottom right cell is the event that R_i doesn't answer q, given that he doesn't know the answer. Its probability should also be quite high, and setting it equal to p_i is not implausible. This assumption simplifies the mathematics.

The third assumption states that $R_1,\ldots R_n$ do not influence one another in their abilities to answer questions and in their referral judgments.

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[9]Recall that this means his being able to answer the question from memory or by looking in the library resources available to him. We stress, of course, the latter in this paper.

$b_1(1-p) = P(\bar{K}_1)P(A_1|\bar{K}_1)$. Note that if R_1 does not know the answer and responds, the answer is taken to be unacceptable to the querist, with penalty c.

The events A_1K_1 and $A_1\bar{K}_1$ thus terminate buckpassing, while either event $\bar{A}_1K_1$ or $\bar{A}_1\bar{K}_1$ means that R_1 refers the question to R_2. The probability of $\bar{A}_1\bar{K}_1$ or $\bar{A}_1\bar{K}_1$ is:

$$P(K_1)P(\bar{A}_1|K_1) + P(\bar{K}_1)P(\bar{A}_1|K_1) = a_1(1-p) + (1-a_1)p = a_1(1-p) + b_1p$$

This probability, or something like it, occurs so often that we call it P_1, the probability of passing the buck, with k=1. If the buck-passing sequence terminates with no answer, the utility of that state is taken to be 0, with V=0.

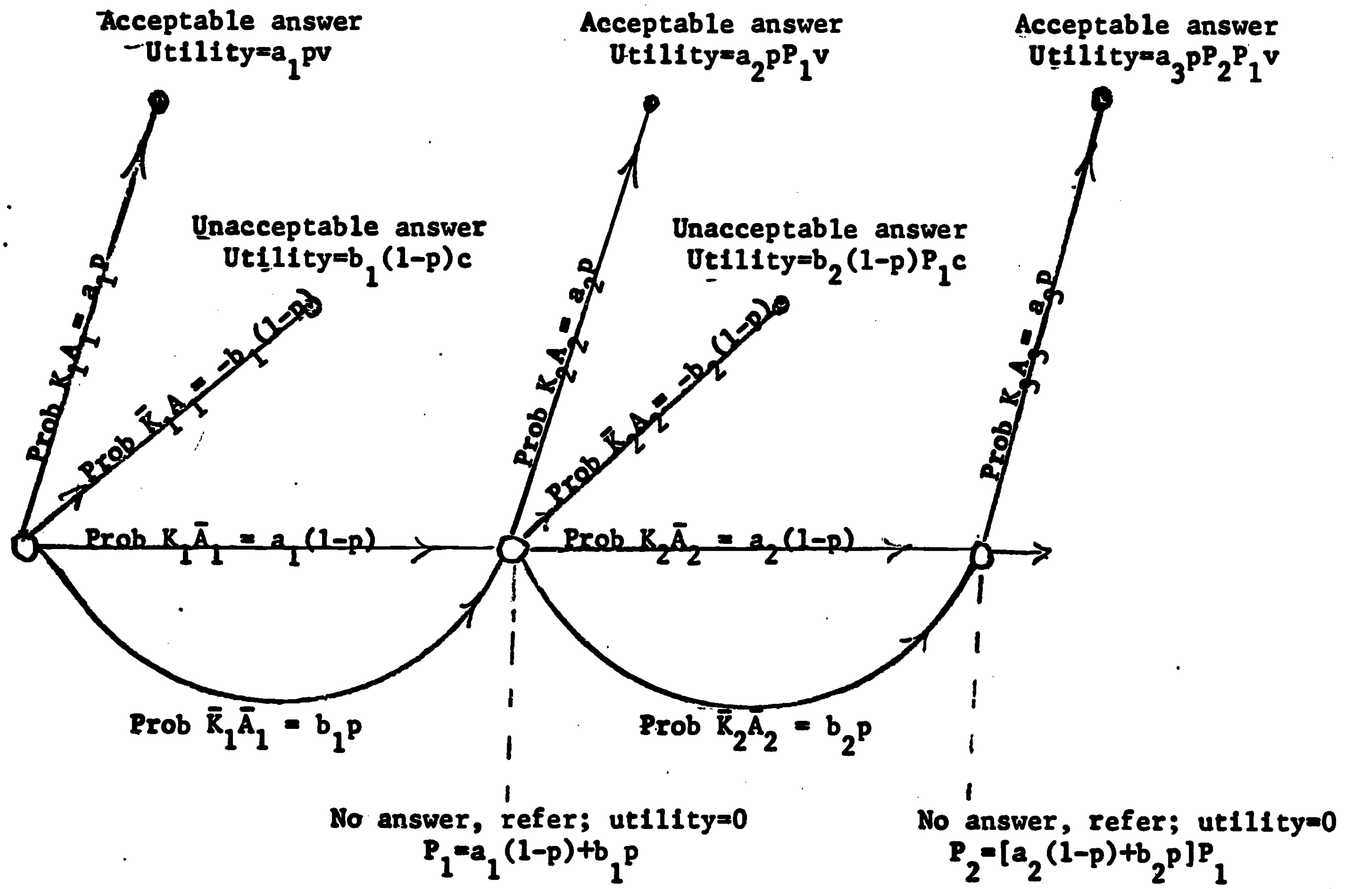

Figure 4

A Diagream for the Buck-Passing Process

Let k be the number of times the "buck has been passed" before the querist gets a response, $k=0,1,2, \ldots, n-1$. Thus if R_1 answers q, $k=0$. If he does not, but R_2 does, then $k=1$. Let t be the total average time (say in hours) elapsed between R_1's receipt of q and the delivery of an answer. If T is the average time it takes R_i, for any i, to consult resources (I) and (II) until he provides an answer or "passes the buck" to R_{i+1}, then $t=(k+1)T$. It would be eminently reasonable to assume that the utility of the answer decreases with t, perhaps as v/t, or as shown in fig. 3; and the cost may increase with t, perhaps as ct.

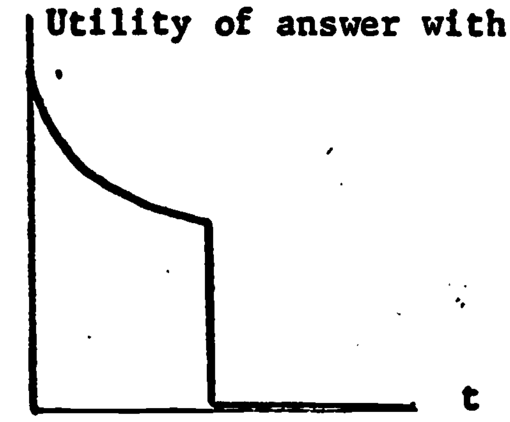

Figure 3
A possible relation between utility and response time

To make a first analysis mathematically tractable however, we make the following assumption.

Assumption 4: The utility of an acceptable answer and the cost of an unacceptable answer does not vary with t, the time it takes to deliver it.

We can now derive a simple expression for V. The expected net utility of an answer from R_1, with $k=0$, is $a_1pv - b_1(1-p)c$, because a_1p is the joint probability of A_1 and K_1, being $P(K_1)P(A_1|K_1)$, and

Figure 4 shows the general calculation procedure. The solid circles stand for terminal states and the hollow circles for "pass the buck" or referral states The probability P_i of R_i being in a referral state, meaning that R_i "passes the buck" to R_{i+1}, is $P_i = a_i(1-p) + b_i p$. Hence, the probability of R_{i+1} being the first to answer q acceptably, without passing the buck, is $\prod_{j=1}^{i} P_j P(A_{i+1}, K_{i+1}) = \prod_{j=1}^{i} P_j P(A_{i+1}|K_{i+1}) P(K_{i+1}) = \prod_{j=1}^{i} P_j p a_{i+1}$, since $p_{i+1} = p$.

The (positive) expected utility is therefore,

$$a_1 pv + a_2 pP_1 v + a_3 pP_1 P_2 v + \dots = pv \sum_{i=1}^{n} a_i \prod_{j=0}^{i-1} P_j, \text{ with } P_o = 1.$$

Consequently,

$$V = pv \sum_{i=1}^{n} a_i \prod_{j=0}^{i-1} P_j - (1-p)c \sum_{i=1}^{n} b_i \prod_{j=0}^{i-1} P_j = pv \sum_{i=1}^{n} [a_i - (1-p)(c/pv)b_i] \prod_{j=0}^{i-1} P_j$$

For assumption (1) we have

$$\begin{aligned} P_j &= [a+(j-1)e](1-p) + [1-a-(j-1)e]p \\ &= a(1-p) + p(1-a) + (e-2ep)(j-1) \\ &= P_1\{1 + [e(1-2p)/P_1](j-1)\} \end{aligned}$$

This formula was evaluated with the help of a computer program. The results are plotted in Figures 6 and 7.

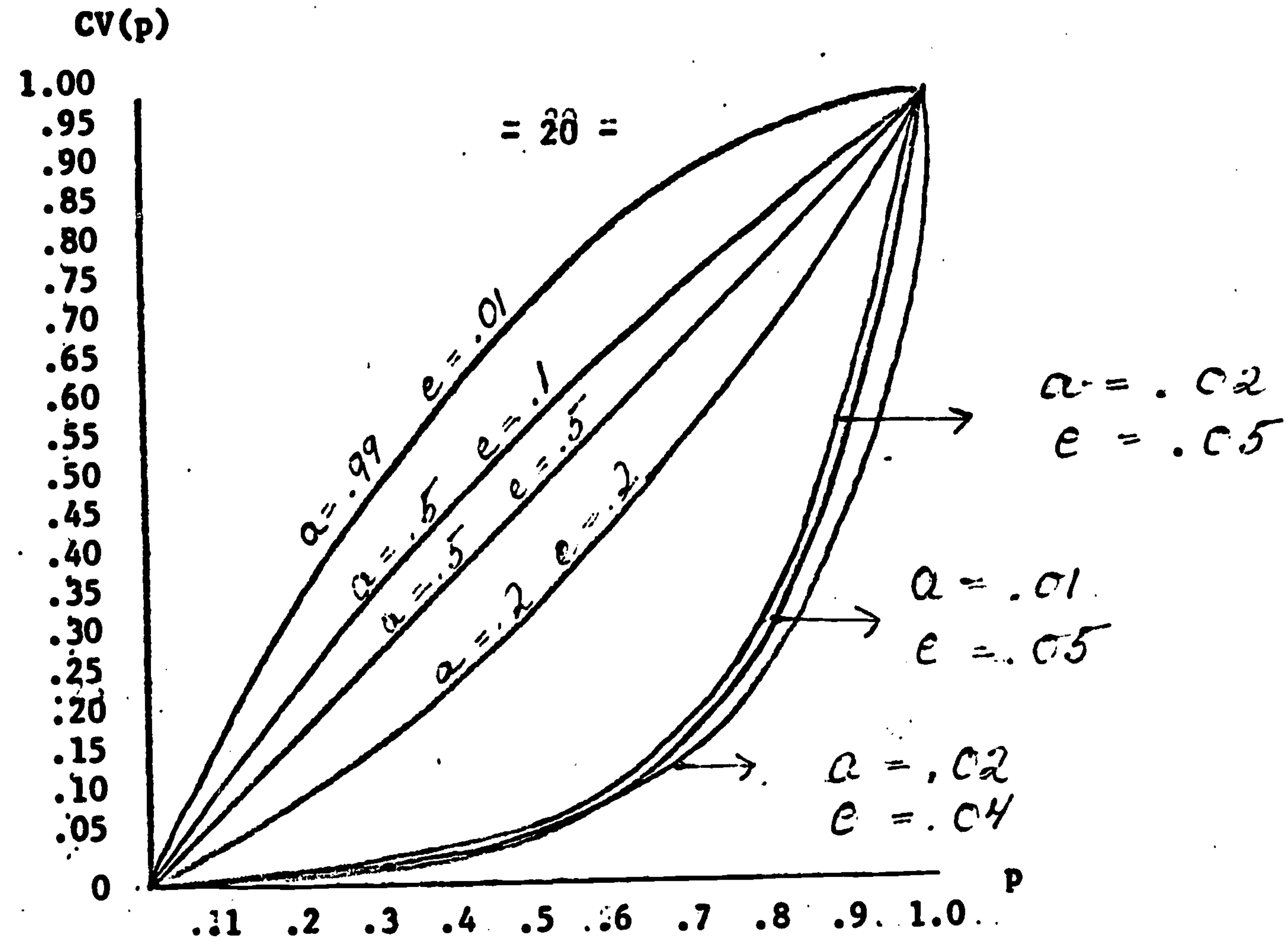

Figure 6
The coefficient of utility vs probability of providing acceptable service.

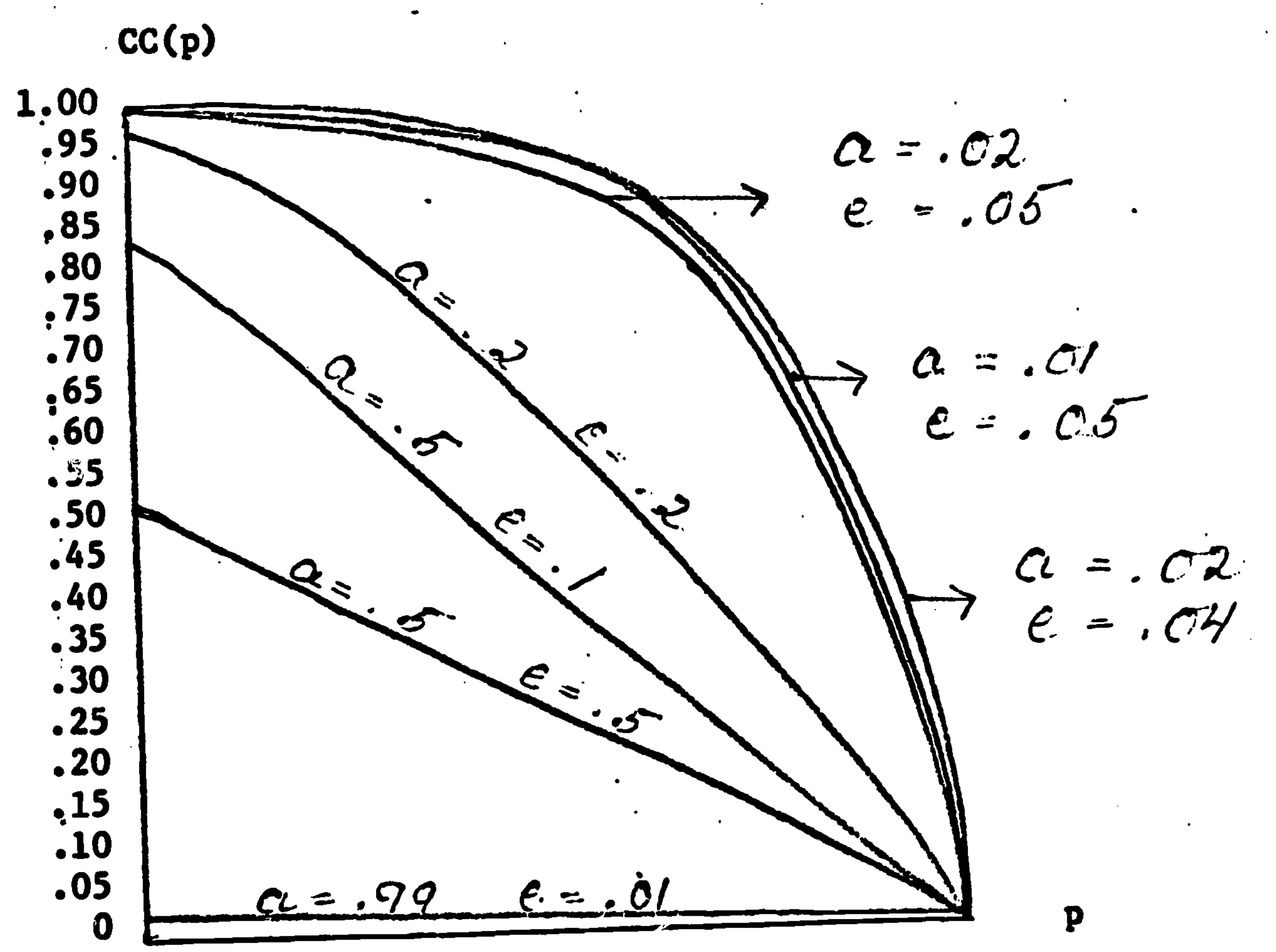

Figure 7
The coefficient of penalty vs probability of providing acceptable service.

The results show that for small values of a and e, the coefficient of v increases slowly with p up to about p = .5, then rises sharply; the coefficient of c decreases slowly with p up to about .5, then drops sharply. For a value of p sufficiently close to 1, therefore, the coefficient of v exceeds the coefficient c by enough to make V positive. That is, in a larger network of referential consultants, under the conditions of this first model, the expected net utility is favorable if each consultant, though he may have a very small chance of answering questions, can very reliably refer it to a colleague whose chances are a little larger.

We express V, for any given values of p, a, and e as $V = (CV) \cdot v - (CC)c$. It is instructive to examine the ratio $\frac{V}{(CC)c} = \frac{CV}{CC} \cdot \frac{v}{c} - 1$. Clearly, V is positive (and large) to the extent that $\frac{V}{(CC)c}$ is positive and large: i.e., to the extent that $\frac{CV}{CC}$ exceeds $\frac{c}{v}$. Let us therefore plot the ratio $\frac{CV}{CC}$ as a function of p for a few values of a and e. Note that the $\ln \frac{c}{v}$ is usually a positive quantity, because c, the penalty of a wrong answer, generally exceeds v, the utility of an acceptable answer. We can denote $\ln \frac{c}{v}$ by the dotted line in Figure 8. The condition that the network results in useful service translates in Figure 8 into the condition that the curve representing the network must be above the dotted line. This can only happen when both a and p are sufficiently large. To satisfy this condition, the larger a, the less p has to be, and the larger p, the smaller a has to be.

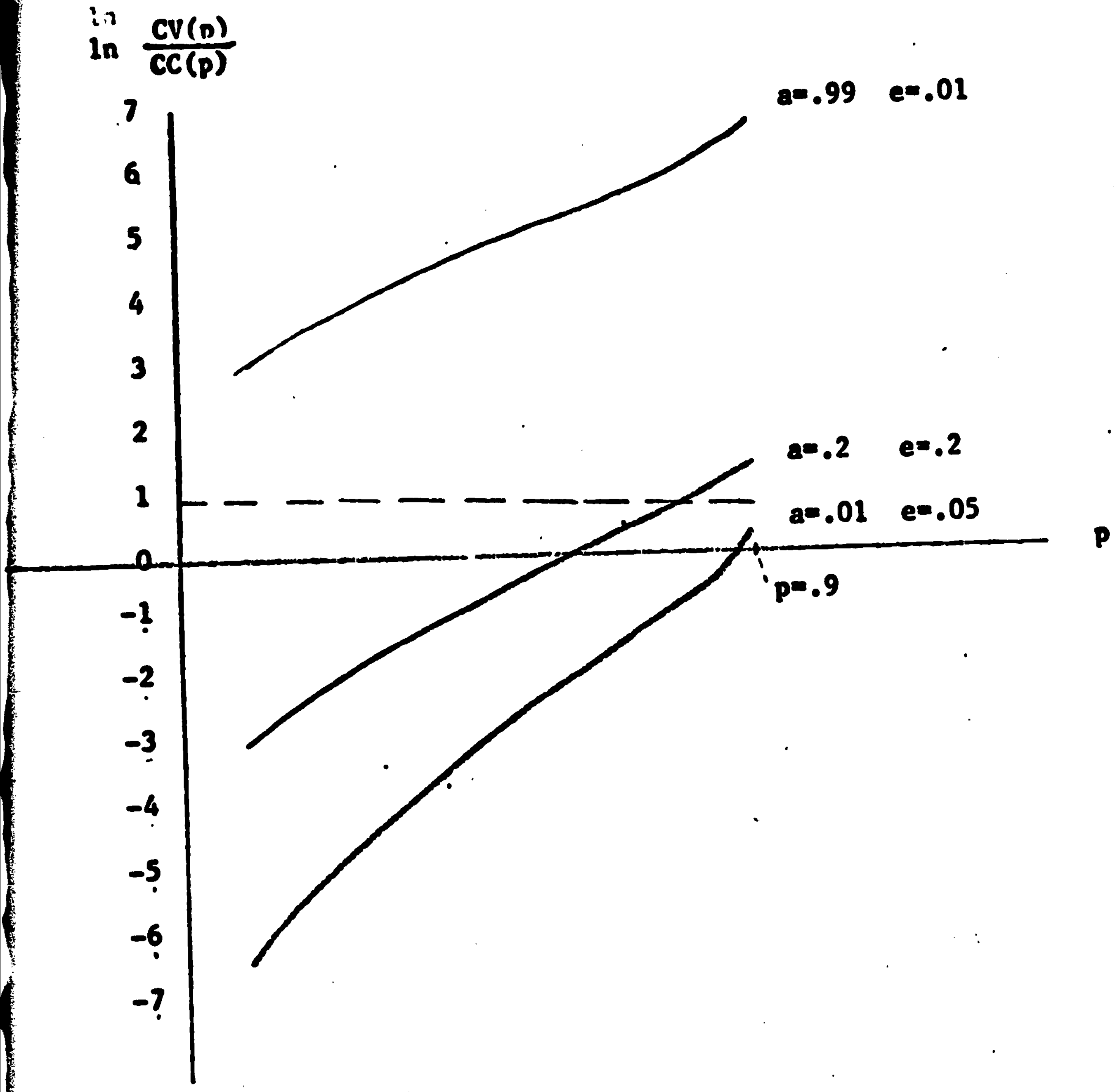

Figure 8

4. A Second Mathematical Model: A Network of Referential Consultants

Even so simple a model as sketched in the previous section gives rise to some moderately complex formulas. These are more easily evaluated by computer than by analytic approximations, although the latter has been done for the formula of section 3. But the model is more interesting for the extensions to which it can easily lead than for its own sake.

The simplest and most interesting extension is to drop assumption 1. In its place we introduce a matrix of n^2-n variables. Let c_{ij} be the probability that if R_i does not answer q, then he refers q to R_j. In other words, instead of passing q to a specific R, the choice of R is now random. Clearly $c_{ii}=0$, for all i, and $\sum_{j=1}^{n} c_{ij}=1$. The query still goes to R_1 initially. The probability, Q_1, that it is answered acceptably after one referral, at k=1, is

$$[c_{12}P(K_2)P(A_2|K_2) + c_{13}P(K_3)P(A_3|K_3) + \ldots + c_{1n}P(K_n)(A_n|K_n)]P_1,$$

where P_1 is the probability that R_1 refers q; it is $a_1(1-p) + (1-a_1)p$. This is

$$P_1 \sum_{j=2}^{n} c_{1j}a_jp_j = P_1p\sum_{j=1}^{n} c_{1j}a_j$$

under the remaining assumptions, namely that $p_j=p$ for j=1, ..., n. The probability that it is answered unacceptably after one referral is $Q'_1 = P_1(1-p) \sum_{j=1}^{n} c_{1j}b_j$, where $b_j=1 - a_j$.

The probability, Q_2, that q is acceptably answered only after two referrals, with k=2, is the probability that R_1 refers it to R_i for some i, which is P_1c_{1i} and that i refers it on to R_j for some j, who answers it. The resulting probability is $\sum_i P_1 c_{1i} P_i \sum_j c_{ij} p_j a_j$,

where $P_i = a_i(1-p_i) + b_i p_i$.

Thus,

$$Q_2 = P_1 p \sum_i c_{1i} P_i \sum_j c_{ij} a_j; \quad Q'_2 = P_1(1-p) \sum_i c_{1i} P_i \sum_j c_{ij} b_j$$

Next,

$$Q_3 = P_1 p \sum_i c_{1i} P_i \sum_j c_{ij} P_j \sum_k c_{jk} a_k;$$

$$Q'_3 = P_1(1-p) \sum_i c_{ij} P_j \sum_k c_{jk} b_k$$

The probabilities that q is acceptably and unacceptably answered after k referrals are, respectively, Q_k and Q'_k, k=0, 1, 2, ..., n-1.

and

$$V = v \sum_{k=0}^{n-1} Q_k - c \sum_{k=0}^{n-1} Q'_k$$

With the help of a simple computer program it is now easy to study the effect of different referral matrices, C. Because the computer program is simpler than the mathematical formulas which explicitly express Q_k and Q'_k , we present the listing of a PIL program. This is the "Pittsburgh Interpretive Language" available on the Michigan Time-Sharing System, and its commands are self-explanatory. There is, of course, no need, with the use of a computer program, to assume that a_i=a+ie, and $a_1, \ldots a_n$ can be arbitrarily specified. The effects of different vectors a can thus also be investigated.

```
>
>     1.01    DEMAND N
>     1.02    TYPE "ENTER A(I) I=1 TO N"
>     1.021   FOR I=1 TO N:  DEMAND IN FREE FORM A(I)
>     1.03    TYPE "ENTER C(I,J) I=1 TO N:   J=1 TO N"
>     1.031   FOR I=1 TO N:  FOR J=1 TO N: DEMAND IN FREE FORM C(I,J)
>     1.04    DEMAND P
>     1.1     FOR I=1 TO N:  SET R(I)=A(I)*(1-P)+(1-A(I))*P
>     1.11    SET CV(0)=P*A(1)
>     1.115   SET CC(0)=(1-P)*(1-A(1))
>     1.12    TYPE CV(0), CC(0)
>     1.13    SET S=0
>     1.14    SET T=0
>     1.2     FOR K=1 TO N:  SET S=S+C(1,K)*A(K)
>     1.21    FOR K=1 TO N:  SET T=T+C(1,K)*(1-A(K))
>     1.22    SET CV(1)=CV(0)+R(1)*P*S
>     1.225   SET CC(1)=CC(0)+R(1)*(1-P)*T
>     1.23    TYPE CV(1), CC(1)
>     1.3     SET BP=2
>     1.4     SET I=BP
>     1.5     FOR K=1 TO N:  SET M(K)=A(K)
>     1.55    FOR K=1 TO N:  SET U(K)=1-A(K)
>     1.6     FOR J=1 TO N:  SET D(J)=0
>     1.65    FOR J=1 TO N:  SET E(J)=0
>     1.7     FOR J=1 TO N:  FOR K=1 TO N:  SET D(J)=D(J)+C(J,K)*M(K)
>     1.71    FOR J=1 TO N:  FOR K=1 TO N: SET E(J)=E(J)+C(J,K)*U(K)
>     1.75    IF I=1, TO STEP 1.9
>     1.8     FOR K=1 TO N:  SET M(K)=R(K)*D(K)
>     1.81    FOR K=1 TO N:  SET U(K)=R(K)*E(K)
>     1.85    SET I=I-1
>     1.86    TO STEP 1.6
>     1.9     SET CV(BP)=CV(BP-1)+R(1)*P*D(1)
>     1.91    SET CC(BP)=CC(BP-1)+R(1)*(1-P)*E(1)
>     1.92    TYPE CV(BP), CC(BP)
>     1.93    IF BP=N-1, TO STEP 1.01
>     1.94    SET BP=BP+1
>     1.95    TO STEP 1.4
>     1.99    DONE
>
```

Figure 9

Listing of PIL program for computing the coefficient of utility, CV and the coefficient of penalty, CC as a function of the number of times the buck is passed, BP = 0, 1, ..., N-1, in any network of N referential consultants.

Notes: Symbol Used Here	Corresponding Symbol in Text	Meaning
N	n	Nr. of referential consultants
A(I)	a_i	Prob. (R_i knows answer to q)
C(I,J)	c_{ij}	Prob. (R_i refers q to R_j | R_i doesn't answer)
P	p	Prob. (R_i answers q | R_i knows answer) = Prob. (R_i doesn't answer | R_i doesn't know answer) i = 1, ..., N.
R(I)	P_i	Prob. (R_i doesn't answer, refers)

This program was run for a number of networks with N=5 and N=7. The ratio of the value coefficient CV to the cost coefficient CC was calculated in relation to C/V. The results are presented in Figure 9. They supported the following general remarks:

1) High ratios are achieved only with relatively high a_i's. Thus the vector $\underline{a}$ = (.2, .4, .6, .8, 1) yielded consistently high ratios. It proved to be the most flexible for all networks.

2) The arrangement of the R_i's in the organization seems to be very important. When the "smartest" R_i was placed first in the network and was supported by a number of 'less smart' consultants, a substantially higher ratio is achieved than if he were placed further along, thus receiving q at a later stage [e.g., (.8, .03, .03, .03, .03) is better than (.03, .03, .8, .03, .03)].

3) Although [as stated in (1)] high a_i's seem to indicate greater ratios, even low ratios can be increased by increasing the size of the network.

4) Note that in many cases, for example, in the case where a_1=.8, a_i=.03 for C= 2, 3, 4, V = .743v - .104c, which is less than V_0= .72v - .02c the net value for a network with the same R_1 but no one else to whom to refer. Here $V-V_0$ = .023v - .084c, which is positive if $\frac{v}{c} > \frac{.084}{.023} > 3$. This shows that if the benefit of an acceptable answer is more than three times the penalty of an unacceptable answer, then the network of referential consultants, gives greater net utility than would the smartest consultant standing alone. Of course, the utilities and penalties of an answer can hardly ever be quantitatively estimated, so that these results are to be used only as qualitative indications of the relations among key variables.

Figure 10
Tabulation by Network

I. The situation in which each R_i refers q to R_{i+1}, i=1, ..., n with the exception of R_r who can refer it to R_{n-1}. No R_i may refer to himself. Two networks, one with 5 R_i's and the other with 7, are considered.

Values of a_i	CV(p) - CC(p)	Ratio $\frac{CV(p)}{CC(p)}$
.8, .03, .03, .03, .03	.743v - .104c	7.14
.2, .4, .6, .8, 1	.851v - .145c	5.86
.03, .03, .8, .03, .03	.613v - .234c	2.62
.01, .01, .02, .03, 1	.605v - .334c	1.81
.01, .01, .05, .05, .4, .4, .8	.561v - .388c	1.44
.01, .01, .01, .02, .02, .03, 1	.500v - .451c	1.11
.01, .01, .02, .02, .03, .03, .04	.093v - .493c	.188
.01, .02, .03, .02, .01	.064v - .391c	.164
.01, .01, .02, .02, .03	.061v - .395v	.159
.01, .01, .01, .01, .01	.036v - .399c	.090

II. A. The situation in which R_1 passes q directly to R_n

Values of a_i	CV(p) - CC(p)	Ratio $\frac{CV(p)}{CC(p)}$
.01, .01, .02, .02, .03	.033v - .186c	.177
.2, .4, .6, .8, 1	.918v - .082c	11.20

B. In this variation of (A) n=7, and q is passed with probability .7 to R_6 and with probability .3 to R_7. The only exceptions are that R_6 always passed to R_7, and R_7 always passes to R_6.

Values of a_i	CV(p) - CC(p)	Ratio $\frac{CV(p)}{CC(p)}$
.01, .01, .01, .02, .02, .03, 1	.831v - .168c	4.93

III. Random buck-passing networks:

A. There is an equal chance of any R_i receiving q

Values of a_i	CV(p) - CC(p)	Ratio $\frac{CV(p)}{CC(p)}$
.2, .4, .6, .8, 1	.8675 - .118c	7.40

B. There is an almost equal chance of any R_i receiving q, but top R_i's have slightly increased probability.

Values of a_i	CV(p) - CC(p)	Ratio $\frac{CV(p)}{CC(p)}$
.01, .01, .01, .02, .02, .03	.526 - .328	1.59
.01, .005, .005, .005, .005, .005, .005	.029 - .510	.057
.005, .005, .005, 01, .005, .005, .005	.026 - .513	.051

C. This is a non-uniform random referral situation according to the following given matrices:

1.

$$\begin{bmatrix} 0 & .3 & .2 & .2 & .3 \\ .3 & 0 & .3 & .2 & .2 \\ .2 & .3 & 0 & .3 & .2 \\ .2 & .2 & .3 & 0 & .3 \\ .3 & .2 & .2 & .3 & 0 \end{bmatrix}$$

Values of a_i	CV(p) - CC(p)	Ratio $\frac{CV(p)}{CC(p)}$
.2, .4, .6, .8, 1	.865v - .188c	7.33

2.

$$\begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

Values of a_i	CV(p) - CC(p)	Ratio $\frac{CV(p)}{CC(p)}$
2., 4., .6, .8, 1	.671v - .193c	3.49

3.

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ .6 & .4 & 0 & 0 & 0 \\ .5 & .3 & .2 & 0 & 0 \\ .4 & .3 & .2 & 1 & 0 \end{bmatrix}$$

Values of a_i	CV(p) - CC(p)	Ratio $\frac{CV(p)}{CC(p)}$
.2, .4, .6, .8, 1	.18v - .08c	2.2

IV. In this situation there is no buck passing at all.

Values of a_i	CC(p) - CC(p)	Ratio $\frac{CV(p)}{CC(p)}$
.01, .02, .03, .02, 1	.009v - .099c	.091

It is quite possible that in an organization, the people R_j with higher values of a_j also rank higher. An R_i of a given rank in some organizations is more likely to pass the buck on certain questions to an R_j of lower rank than to a superior. In this case, c_{ij} would increase as a_j decreases. This is quite unfavorable.

The model studied in the previous section is a special case of this model with $c_{i,i+1}=1$, for i=1, 2, ..., n-1, but $c_{nj}=0$ for all j. (R_n could never refer, violating the condition $\Sigma_j c_{ij}=1$). In the present model, the question can get trapped in a bureaucratic cycle, and we can calculate the probability of this happening. For example, it is possible for R_1 to refer q to R_5; R_5 could refer it to R_9, R_9 to R_3 and R_3 back to R_1, with R_1 referring it this time to R_2, etc. The question could eventually traverse through all the R_i in all possible paths and stay in the network for an infinitely long time.

5. Toward Greater Realism

Some severe limitations of the models considered so far, beyond those formally stated before, are described next.

(a) The question was taken to be unchanged, as first presented by the querist. No provision for conversing with the querist has been made. Suppose now that any R_i to whom q is referred can converse with the querist. Indeed, we might include the querist -- let us call him R_o -- in the network: R_o, R_1, ..., R_n. The question can occassionally be referred back to him. This would make sense only if we permitted each R_i a fourth resource beyond (I) his memory,

(II) his auxiliary memories (library items), (III) access to other R_j: namely, (IV) his ability to reinterpret, reformulate, substitute for q or to ask R_o questions in place of either providing an answer or "passing the buck". The latter would permit R_o to reformulate, reinterpret or substitute for q. This process may improve the quality of the question.[10] Of course, we would need to characterize R_i by an additional variable: d_i = Prob.(R_i converses with $R_o|\bar{A}_i$).

(b) The variables characterizing R_i, namely a_i, p_i, p'_i, d_i, were taken to be independent of the question q, and unchanging in time. Suppose that questions can be classified and graded, a job that R_1 might do. Suppose that R_1 works with m categories $C_1, \ldots, C_m$, such as specialties in which various R_i have expertise. Then, in place of a_i, we have a_{ij}, the probability that R_i can answer a question in category C_j. If R_i is an expert only in specialty C_j, then a_{ij} is high and a_{ik} for $k \neq j$ is low. These question categories could not only aggregate questions by common subject matter, but by quality as well. Thus, a_{ij} may be low for all j if C_j is a category of poorly formulated questions, while a_{ik} may be higher for all k where C_k is a category of well-formulated questions.

We could now further specify the system by giving the a priori probabilities of a randomly chosen question falling into $C_1, C_2, \ldots, C_m$; call these $r_1, \ldots, r_m$. Let s_{ijk} = Prob [q is reformulated so that it is transferred from C_j to C_k, given that R_i converses with

[10] For an interesting analysis of the structure of the negotiating process, see Taylor (22).

R_o]. Hence, $d_i s_{ijk} \cdot a_{ik}$ is the probability of R_i's conversations with R_o resulting in an answer to the revised question, given that R_i did not answer it previously. Of course, there is a price for delay.

This permits us to compute the probability with which "buck passing" can upgrade the question. For lack of space this must be deferred for future investigations.

(c) The matrix C embodies a referral strategy and organization. This might, however, change for questions in certain categories. The categories $C_1, \ldots, C_m$ could reflect priorities assigned to questions. A high-priority question might always immediatey be referred to the R_i with the highest a_i, and he might refer it, or fragments of it formed by him, down the line.

(d) The discussions so far have assumed only person-to-person messages (questions and answers), but no "to whom it may concern" messages. Certain questions reaching R_1, could be broadcast by R_1, with an instruction that whichever R_i could readily answer q should speak up. The motivation in such a system for "speaking up" would have to be at least that of the R_i to whom a question was referred in the "buck passing" organization. If time is a very important factor, then this inherently parallel system may be preferable.

The models for analyzing such a system would be based primarily on a reinforcement function which: greatly rewards the R_i who spoke up, i.e. supplied the answer for a q such that his a_{ij} is very high; moderately rewards the R_i whose a_{ij} is low and who does not speak up or the R_i whose a_{ij} is reasonable, but who converses with R_o; punishes the R_i whose a_{ij} is high and who does not speak up or the R_i whose a_{ij} is low and who does speak up. If no one speaks up, some reward might go to the R_i who refers q to an R_k for whom $p_k a_{kj}$ is high.

The use of such a reinforcement schedule should result in learning, and the values of the p_i, p'_i would change with time.

(e) Finally, there is the question of organizational design. We assume that requests originate randomly at various geographic locations in a community. The average time to forward a question to the nearest R_i may therefore vary depending on where he is located. Perhaps there should be more than just one R_1, to each of whom all requests in his service area are initially forwarded. (11) Or, perhaps having the service "areas" arranged by topic, rather than geographically, with the querist deciding upon the nearest topically specialized R_i to whom to forward q has high utility.*

Within the community of the R_i, similar questions arise. There is an additional question involving the number of R_i with the same a_{ij} to use redundantly, so as to handle expected loads. This is a problem in the analysis of querying networks such as studied by R. Disney (4), and an aim of organizational design is to balance idleness and congestion.

*This is currently the case for many of the questions cited earlier in this paper.

6. Some Problems for Further Research

(a) Even in the simplest model of section 3, what is the best point to enter a chain of R_i's? If there is no basis for assigning questions to R_i's, and if a_n is largest, then why should not all questions go initially to R_n? This would certainly be optimal from the user's viewpoint. Too, the smaller the x, where R_x is the one to whom q is initially submitted, the greater the probability of an unacceptable answer. The probability of the first acceptable answer occurring after the k^{th} referral since R_x received q, is

$$p \sum_{i=x}^{x+k} a_i \prod_{j=0}^{i-1} P_j$$

The average net utility, if q is initially received by R_x is

$$V(x) = pv \sum_{i=x}^{n} [a+(i-1)e] \prod_{j=0}^{i-1} P_j - (1-p)c \sum_{i=x}^{n} [1-(a+(i-1)e] \prod_{j=0}^{i-1} P_j$$

We can now seek the value of x which maximizes this expression.

(b) Suppose that a querist R_o poses several questions to R_1, each belonging to a subject category C_j, and each was referred by R_1 to R_i, and in each case R_i provided an eminently satisfactory response. R_o will soon learn to pose any future questions in C_j directly and initially to R_i.

In practice, much more than half of all questions posed by R_o may fit into no more than a dozen categories, for each of which there may be an R_i whom R_o has learned to contact initially, once he has classified the question himself. What advantages, then, does a referral network offer?

First, not all querists will have questions fitting into the same dozen categories. It may still be the case that well over half of the questions posed by anyone fall into a few dozen categories, and users may have learned to contact experts on these categories directly. The referral network then serves to teach users where to turn. This is important when the user population is constantly expanding, with an overwhelming and growing fraction of all users at any time being untrained, young newcomers.

Secondly, users may be less able to usefully categorize their own questions than could R_1. This too, can be learned, but such learning is a continuing process for the less than half of the questions that do not fall into less than a dozen categories. Any system which will be able to handle these very many relatively rare and, hence unusual, questions is bound to be expensive, because it has to be customized. This is a very important area in need of investigation.

Third, and perhaps most important, knowledge, and, perhaps wisdom also (10), are constantly growing. This means that the categories constantly change and that the set of questions that could be answered is continually expanding. Conversations between R_o and the R_i he contacts, which can and should serve to teach R_o which questions he might ask that he had not thought of or known to ask, play an increasingly important role. Here, a referral network offers the advantage of a multiplicity of potential teachers, and, therefore, a greater opportunity of finding treasure.

(c) The models (i.e., mathematical problems sketched and suggested here) are useful for clarifying essential concepts. They stimulate precise new ideas. They also serve as vehicles for developing methods of, and experience with, mathematical analysis. But they cannot lead to theories until they are connected with empirical or experimental data. A whole class of research problems suggested by this kind of mathematical thinking involves data acquisition.

To some extent, special libraries already perform an expanding reference function. By monitoring samples of the memoranda[11], telephone, and personal calls from R_i to R_j in such an organization, crude estimates of the matrix C can be obtained. A far better study, however, would be a controlled experiment in which a sample of questions is planted, i.e., submitted to an existing question-answering network of referential consultants $R_1, \ldots, R_n$, such that the consultants cannot distinguish these planted questions from the ones they normally encounter. All the planted questions have definite answers. The experimenter may even know whether or not the answer to a given question is known to R_i via library resources (II) [aids to memory]. That is, the experimenter may have chosen the question because he has seen the answer in the reference collection which is within R_i's reach. Such an experiment may then permit us to estimate p_i, p'_i, a_i, c_{ij} and d_i for $i=1, \ldots, n$, and to test certain key predictions of one or another set of assumptions.

[11] At least one origin-destination study of inter-office memoranda was done at IBM by Resnick et. al., but of course the content was not examined nor were many of the memoranda questions such as may be transmitted to a referential network.

(d) Another important line of experimental investigation involves categorization of the queries and specialization of the referential consultants. In our models, we have mixed three different bases for categorization: by specialty; by priority; and by question quality. There are undoubtedly more. Categorization by specialty is traditional (this is the sense of "special" in special libraries) and superficially the simplest, but it rests on a very weak theoretical foundation.

It is today no longer so important that R_i get only questions to which his library resources are specialized, because he has access to an apparatus for bibliographic control over resources beyond those which are literally within walking distance. The limitation lies in R_i's ability to use this apparatus after the limits of his own expertise about the question are exceeded.

What probably matters most in a categorization of questions and R_i's is the quality and priority of questions. In comparing two categorizations of a corpus of 100 questions, say $[C_1, \ldots, C_m]$ and $[C'_1, \ldots, C'_m]$, we might well ask which gives the greater value for

$$\max_i \max_j p_i a_{ij} \text{ or } \Sigma_i \max_j p_i a_{ij}$$

where a_{ij} is the probability of an acceptable answer from R_i to a question in category C_j or C'_j. This can be decided by data. One possible experiment to do this would be to categorize a sample of planted questions in two different ways and to broadcast with each question an appeal to all the $R_1, \ldots, R_n$ for volunteers (to be rewarded) who can most easily and expertly answer it. The sample of questions is carefully chosen so as to fit into a priori designed categories by definition; data about who responds to these questions, and how successfully, is then used to determine how consistently the same R_i picks questions in C_j and is characterized by very high $p_i a_{ij}$.

(e) Another very important line of experimental investigation involves the utility and cost measures. Basically v is the amount a querist is willing to pay per question for an acceptable response delivered in the minimum possible time. This value was taken to be averaged over all questions and querists. In a categorization of questions by priority, however, each question class is characterized by a different value of v. Questions of the class with highest v are of top priority.

Each question which enters the system is part of a submitted form with at least 3 parts:

(i) The initial formulation of the question, including at least some background and hints for the referential consultant as to what kind of answer is wanted

(ii) some indication of how much the querist values the answer, including how his utility for the answer decays with response time

(iii) data about himself, such as would relate to estimating a_{oj}, $j=1,\ldots, m$

This may be done by experimenting with a sample of querists, asking them to allocate a certain sum of money given them by the experimenter over a given list of possible question-answering sources. The list might include elements like: (i) act as your own referential consultant, using (1) and (2) for a particular library resource (II); (ii) same as (i) except for a different library resource (II); (iii) refer to R_1; (iv) refer to R_2; etc.

It is important to bear in mind that R_o can always choose between many competitive sources in getting an answer to his question. By going to R_1 he ought to be assured that R_1 could point him to at least those sources he would have known about himself. If R_o can do R_1's job better by himself, he should, of course, do so.

(f) The cost of maintaining a referral network is likely to be high. The practicality of such a service hinges critically on the rate at which gross revenues grows relative to operating costs. Both will increase, though the service cannot be viable unless revenues grow faster than do costs. If they grow at the same rate, there must be a sizable constant difference of revenues over costs. This state can hardly be claimed to exist for current reference services. Budgets for library services are generally a small part of overhead and are the first to be cut if the total budget is reduced.[12]

Beyond the cost of maintaining the services of n referential consultants in a network are costs generated by the existence of the network itself. According to Parkinson's Law (16), the $R_1, \ldots, R_n$ will generate and send questions and answers to one another. Such messages would not have been generated if there were no network.

[12] The cost factor is one reason why industrial libraries have achieved such success. Not only do they have sufficient funds, but also they are able to assign a definite monetary value to correct information.

The volume of such message traffic may vary as n^2. This limits each R_i's capacity to answer client-generated questions and may necessitate larger n to handle a specified load.

Such internally generated communications are often considered unproductive. Many consider it unprofessional to "pass the buck". Yet, "buck passing" can be a sign of both very irresponsible or very responsible professional behavior. Referring a question is professionally very responsible when it reflects the professional's understanding of his own limitations; such a professional is much more valuable than one who never refers, unless the latter is omniscient. The very irresponsible buck passing professional can be easily discriminated from his opposite by noting that he answers very few questions adequately, and is valued so low as to be dropped.

The communications generated inside the network could be productive. They could help upgrade the organization by helping the R_i teach, and learn from, one another. The measure of learning is the number of good questions R_i can ask that he could not have known to ask before. Conditions for such learning to occur could be derived; a cost-effectiveness model, backed by data, can readily be set up and used to contribute to arguments for the economic feasibility of referential consulting.

7. Conclusions

We have argued, in this paper, for the significance of "referential consulting." This is a new type of service to be performed by a new breed of reference librarian. It resembles expanding reference functions now practiced to an extent in some special libraries. But it goes as much beyond contemporary reference service concepts as these go beyond book delivery service concepts. In essence, referential consulting is a means of providing some kind of useful response to almost any question of importance to people in their daily lives, either by having a member of an organization of referential consultants rely on his expertise, on the library resources at his command, or on his ability to refer the question to a colleague in the organization or outside. The response may be either a direct answer, a document likely to contain the answer, or advice to go to a document or another source. A referential consultant is a very mature, learned, responsible "information officer", an essential, highly valued professional in the community.

Some investigators (1) claim that today's reference librarians already have the status of professionals like doctors, engineers, lawyers, etc. The fact that some librarians already believe this, is a hopeful sign that referential consulting is feasible. A small number of practicing librarians who were casually interviewed stated that questions such as the ten examples of section 2 reach them frequently. Though they were not prepared in library schools to answer them, on the ground that such questions are outside a reference librarian's responsibility, they rarely turn them down. Indeed, they can often give the user acceptable answers.

The very fact that libraries do contain the necessary resources to provide such services reaffirms the need for expanded referential consulting in order to utilize these library resources more effectively and to perform library functions more satisfactorly. We have redefined the function of a library to be:

> to maximize the greatest potentially attainable effective and efficient social utilization of documented knowledge.

Hopefully the models of referential networks presented here will stimulate ideas and actions to be more nearly consonant with this definition.

We have assumed that there is a latent need for such a referential consulting service. This need will be made manifest if people will use, request and pay for the referential consulting service if it is offered. We therefore recommend -- urge -- the creation of such a service. We predict that it will create demand and, in time, pay for itself. Part of this recommendation is addressed to library science educators, to educate some of the high-level professionals capable of serving as referential consulting services, to educate innovators, scholars and scientists who can advance and develop the concept and the underlying rationale and discipline.

We have begun an explication of the "referential consulting" concept. Though crude, it has proved capable of clarification, of leading to further ideas and of providing some results. We have derived conditions under which various forms of the referential consulting organization lead to maximum or specified expected net utility.

Even our first step toward an explication of the concept of referential consulting service reveals a number of exciting intellectual puzzles. To investigators inclined toward mathematical thinking, they can be a challenge inviting further exploration. To investigators inclined toward observation, they can suggest useful, empirical or experimental studies. One study, if done well, can lead to another and, in time, toward a theory of an important aspect of librarianship.

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ABSTRACT

We explicate the concept of a network of consultants to help people obtain answers to day-to-day questions for which answers are known. Each member of such a network is viewed to have three capabilities: 1) answering questions directly from his own memory; 2) answering questions with the aid of library resources; 3) referring the question to a member of the same network or to an expert outside it. We derive conditions involving each member's ability to choose appropriately among the three alternatives. If he judges correctly concerning when and where to refer a question, such a network, suitably organized, has greater net utility than does a reference librarian by himself.

We argue that the existence of such a network makes possible a much broader range of information service to the community than is afforded by traditional reference librarianship.