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ABSTRACT

Telecommunications planning is viewed as a decision problem in which a decision maker must select among several alternative telecommunication systems with different costs and performance characteristics. In some cases the decision will involve comparison of alternatives with outcomes that involve the behavioral responses of users to the system, and these responses may be difficult to measure. In other cases outcomes may only be predictable on a probabilistic basis. In all cases the decision maker needs a systematic way of expressing his values in the form of tradeoffs among the outcome dimensions. A decision framework that encompasses all of these issues is presented along with an example of its application to a hypothetical decision problem for a library system involving a tradeoff between communication line costs and user terminal costs. (Other papers from this conference are available as LI 003360 - 003374 and LI 003376 through LI 003390) (Author)

PRINCIPLES OF TELECOMMUNICATIONS PLANNING

by

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ABSTRACT

Telecommunications planning is viewed as a decision problem in which a decision maker must select among several alternative telecommunication systems with different costs and performance characteristics. In some cases the decision will involve comparison of alternatives with outcomes that involve the behavioral responses of users to the system, and these responses may be difficult to measure. In other cases outcomes may only be predictable on a probabilistic basis. In all cases the decision maker needs a systematic way of expressing his values in the form of tradeoffs among the outcome dimensions. A decision framework that encompasses all of these issues is presented along with an example of its application to a hypothetical decision problem for a library system involving a tradeoff between communication line costs and user terminal costs.

INTRODUCTION

The objective of this paper is to present a general framework for telecommunication system planning into which specific information on cost and performance of individual components can be put. The viewpoint taken is that of a decision maker responsible for deciding on the form of a telecommunication system to provide access to remote information for a user community such as a university, a city, or a professional user class such as lawyers or nuclear physicists. Such a decision maker must normally decide among alternatives that can be produced from existing technology or from minor modifications of existing technology, such that precise performance characteristics, delivery time, and price information is available. However, in some cases where there is adequate lead time, it may be feasible to consider alternatives that involve some amount of technological development. In such cases the output of the development program will be to some extent uncertain, and it will be important for the decision maker to be able to estimate the degree of uncertainty and to provide for this aspect of the decision problem in his plans. There are well developed systematic techniques for dealing with uncertainty [1]-[5] that can be applied to this problem and these techniques are described briefly herein.

The basic framework for telecommunication planning that is presented here is built around the decision model [1] of Figure 1. This model is important to an understanding of the decision process, because it allows us to separate any decision problem into a number of clearly defined elements. We may or may not be able to give a precise form to each element of Figure 1, but by attempting to do so we can become aware of the

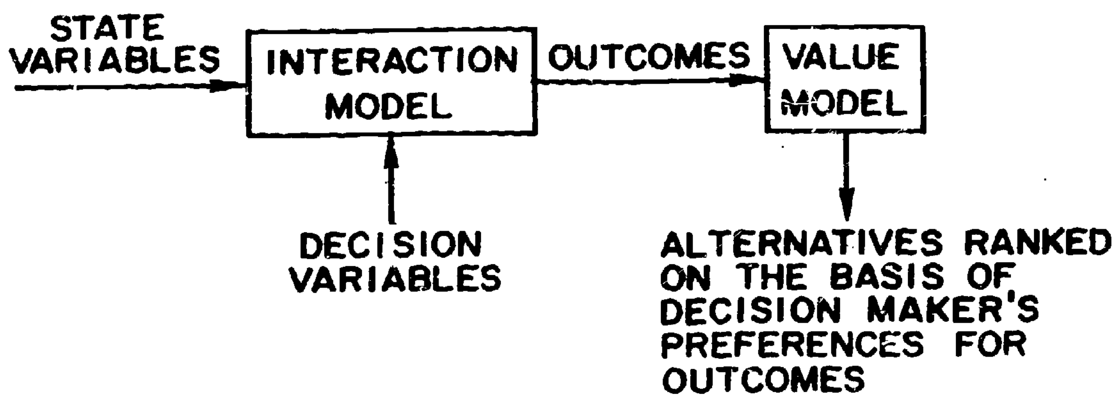


Fig. 1 A model of the decision process. The decision process can be viewed as a choice among several alternatives on the basis of the decision maker's preferences for the predicted set of outcomes associated with each alternative.

precise nature of the information that may be lacking and decide whether or not to attempt to acquire the missing information.

In Figure 1 there are two types of variables: (1) decision variables, which are variables under the control of the decision maker, such as the system performance specifications; and (2) state variables, which are variables not under the control of the decision maker. For a library administrator decision maker an example of a state variable might be the regulatory policy adopted by the FCC with respect to interconnection of private networks with the public switched network. For the FCC as decision maker this variable would be a decision variable. A decision maker is normally confronted with a limited set of alternatives. An alternative consists of a complete set of decision variable "settings" in a particular decision problem. For example, in the present context an alternative might be a specific complete system design.

Outcomes are the results associated with each particular choice of a system alternative in the context in which the alternative is to be implemented. The interaction model is whatever model we may have to predict outcomes, and it may be only a very simple verbal model or it may be a mathematical or computer model. Outcomes can be specified in various degrees of detail and at various levels. For example, we will almost certainly be interested in the outcome that the system perform according to its specifications and be delivered and in operation on time at the cost specified. The cost and technical performance can be viewed as outcomes; in most cases these dimensions of the outcome will be predictable with a high degree of certainty. We would normally also be interested in outcomes related to the use of the system after it is installed. For example, the extent of its usage, by whom it would be used, what time cycle of usage might occur, and the opinions of the users would all be important outcomes.

Finally the decision maker must be able to provide some kind of value model in order for him to decide among competing alternatives with different outcomes. At the very minimum, the decision maker will be required to choose among alternatives with different costs and different technical performance characteristics. He will have to be able to specify his tradeoffs between performance characteristics and cost in order to state which alternative he prefers. If he considers probable behavioral outcomes such as usage he will have to consider tradeoffs at this level as well.

In the following sections of this paper a typical telecommunication system is described in terms of its basic functions, its components, and its performance characteristics. Alternative system configurations are considered in terms of costs and in terms of a set of performance dimensions such as data rate of access messages, daily usage in hours, etc. Then a typical hypothetical decision problem is considered that hinges on the tradeoff between terminal costs and communication line costs. An example of an uncertain outcome is considered as a part of this example. Finally, consideration is given to a value problem in which a decision maker must decide between alternatives that differ in the form in which the cost information is available. For one alternative the cost is given as a fixed dollar amount; for the other the cost may be either of two values and the probability for each cost value is given.

DESCRIPTION OF A TELECOMMUNICATION SYSTEM

A telecommunication system can normally be analyzed in terms of the costs and performance of three major hardware components: (1) user terminals; (2) communication lines; and (3) the central computer and data storage system [6]-[9]. In addition, a substantial cost in most systems is associated with the software that enables the user to operate the system simply and efficiently. Maintenance and operating costs can either be associated with each of the above subsystems or lumped as a single separate item.

The functioning of a telecommunication system designed to provide a library-type service can also be described in terms of a sequence of steps that constitutes a single transaction, as follows.

1. User indication of desire to use the system
2. System indication that it is available or not
3. User indication of data sought to be accessed in terms that can be accepted by the system
4. System indication that data sought is or is not available
5. System provision of data sought to user
6. Recording of usage made of system for charges or other use
7. System indication that transaction is complete and its availability for another transaction

In the above sequence of steps, Steps 1, 2, 4, 6, and 7 are usually referred to as signaling functions analogous to the dial tone and ringing or busy signal of the telephone system and, of course, may in fact involve these telephone signaling functions. Step 3 is a low data-rate (usually less than 300 bits per second) operation that may take the form of a voice conversation, a teletyped statement to a computer, or a conversation with a computer programmed to ask the user a set of questions that can be answered in various simple ways like a multiple-choice test using a teletypewriter or a Touchtone pad.

Step 5 is the key step in the operation as far as system design is concerned, and a number of alternatives are open to the designer at this point. A cathode ray tube (CRT) display of the data is typical, with some separate provision for making a hard copy being necessary if desired. A critical distinction must be made at this point between systems designed to transmit only certain pre-specified characters and systems designed to send arbitrary patterns of data such as photographs of persons or scenes. One page of ordinary written text, when viewed in terms of characters (characters require about six bits per character to store or transmit), represents of the order of 10,000 bits of information. The same page of text or a page with a diagram or a photograph, when viewed simply as an arbitrary page of bits that can have any arbitrary pattern, represents of the order of 1,000,000 to 10,000,000 bits of information. A critical feature of this distinction insofar as the cost of a telecommunications link between the user and the central file is the data rate needed to transmit the message. If the message consists only of standard characters, it is possible to transmit such a message about as rapidly as it can be read or skimmed by a human over a voiceband line. If the message is a sequence of unrelated diagrams or photographs, a much greater data rate is necessary; a television signal is capable of transmitting data at a rate sufficient for this purpose. In most cases, however, the user will wish to examine a series of pages of text or diagrams or photographs with substantial viewing periods per page (up to minutes per page). In this a case a much lower average data rate is required to transmit the necessary information than is the case if there is a rapid sequence of arbitrary patterns. In order to take advantage of this possibility for lowering the cost of data transmission, however, the user terminals must have data storage capability, which increases their cost. A basic system design tradeoff thus exists between local storage costs and data transmission costs.

A variety of options also exists in the design of the central data storage and retrieval system. For example, data may be stored magnetically in core, on discs, or on tape with different resultant access times. Data may also be stored in microfilm and read out by stopping the film for viewing by a particular user. However, the cost of tying up the full system may be very high, if this is done. Therefore, some type of buffer system may be appropriate, to provide temporary data storage and to allow the main microfilm system to be used by other users in more rapid sequence. Such choices depend on the number of users sharing the system and their habits in terms of the average length of usage period and frequency of usage. Readout system options also include the question raised earlier of whether data is to be read out in the form of characters which can be economically coded for low cost transmission at moderate data rates or in the form of a scanned system like TV or Xerography which can handle either pictures or text but which requires far higher data rates than a character transmission system.

System performance characteristics of interest to the designer include those mentioned above plus a number of others that relate more to how the system is to be used, such as average usage in hours per user per day. A number of these performance characteristics are listed below, along with a summary of those suggested above.

1. Data rate of user transmission of description of data sought (Typical: 100 bps)
2. Data rate of transmission of data to user (Typical: 1000 bps)
3. Mode of display of data to user (Typical: CRT display)
4. Total amount of data displayed to user at one time and duration of display (Typical: one page of text displayed for as long as user wishes)
5. Capability of system to provide a hard copy to user
6. Degree of privacy offered to users
7. Total amount of data in central file
8. Classification system used to access data
9. Form in which data stored-access time
10. Sharing capability of central file - buffering
11. Pattern of usage - hours per day per user, number of users, probability of more than n users seeking to use the system simultaneously, etc.

EXAMPLE OF ALTERNATIVE SYSTEM CONFIGURATIONS

As an example of the type of choice that might be offered to a decision maker, a specific set of alternatives is presented next that emphasizes the tradeoff in system design between telecommunications line data rate and terminal complexity.

Let us first consider a system with a central data file subsystem that stores only written text in the form of uniform, standardized characters and that is capable of transmitting characters in the form of a standard code with, say, six bits per character. With an average of five characters per word at a rate of 2000 words per minute such a system can transmit faster than a human can normally read and at a rate sufficient to allow quick scans of the material without much waiting time. The corresponding data rate is 2000 x 5 x 6 x 1/60 or 1000 bits per second (one kilobit per second). The average telephone line can transmit 2000 bits per second, so this system easily falls into the category that can use such a line.

If the central data system stores ordinary text in the form of microfilmed pages, this system requires a high speed character recognition and scan system to encode this data, character by character, and convert it to electrical impulses. Such an encoding system would be feasible, although costly, and an alternative would be a much simpler TV raster type of scan system that would, however, require a much greater data rate in order to transmit the signal to the user. A typical value might be of the order of a thousand times the value obtained with efficient coding or 1 megabit per second rather than 1 kilobit per second. Consequently the line costs would be much greater for such a raster type system. The raster type system, however, has other advantages. At 1 kbps we noted that the "paint-on" speed or the speed at which a picture would appear was about 2000 words per minute which is a moderate scanning speed for a human. At 1 Mbps, on the other hand, the page would appear essentially instantaneously.

Another related tradeoff in this system occurs at the user terminal where a raster type display turns out to be a very simple and low cost approach. TV sets already are available in every home, so if the system were for home use this fact would be very important, and would favor the use of a raster display. The length of time the information needs to be displayed to the user is a critical performance dimension here. Normally a user wishes to be able to look at the information as long as he wishes, up to minutes at a time. If this capability is to be provided, either the information must be stored locally or it must be continually retransmitted from the central data file until the user is through, as in the case of the usual raster display. The consequence of this approach is that a full TV bandwidth is consumed in simply retransmitting old information with its associated high line cost. The basic alternative is a user terminal with sufficient local storage to remember the contents of one page.

One solution is, of course, to make a hard copy. This solution provides both long and short term storage and frees the central data file for other tasks as soon as the information is sent once. However, it is difficult, noisy, and costly to produce hard copy at the speed suggested at the beginning of this discussion using present technology, such as line printers. There are two other major alternatives for the user terminal with storage. The first involves conventional magnetic core storage to store the received information for each character using an ordinary computer memory. The present cost of this type of storage for a full page of of text (about 10 kilobits in the form of characters) is of the order of $1000 or more. The other alternative would use a magnetic disc to record the information in one TV frame (about 1 to 10 megabits in the form of an arbitrary pattern). Such a technique would allow the use of a TV raster system, but would require the signal to be sent only once. It would then be repeated by the magnetic disc as long as the user wished to view it. Such a system could equally well be used to store pictures or other non-character information. It would allow a burst of information to be sent using the full TV bandwidth for 1/30 second (the time of one full frame) and it would retain this information locally until the user asked for a new frame. Obviously such a system would have the advantage of freeing both the central data file and the wideband channel used to send the information to serve other users on a time-shared basis. Such a system can be imagined as a service offered to homes via cable television during the next few years [10].

We are now in a position to formulate several basically different system alternatives that, if this were a real problem, could be costed out in detail. Here we will assign some hypothetical cost figures to each alternative in order to pose the problem for analysis in a specific form. In all cases we will assume that the central data file is the same, except for the presence of the character reader and encoder which we will use for some systems in place of the TV camera that will be used for the raster-type system alternatives. A list of the components available for this hypothetical system is given in Table 1 and illustrated in Fig. 2

Alternatives can now be described simply by the letters associated with the components in Table 1 and three system alternatives are shown in Figure 3. In addition, we must specify the number of users to determine

Table 1

Components and Costs for Hypothetical Library Systems

	Component	Hypothetical Cost
A	Central data file	$1,000,000
B	Character reader and encoder	$ 100,000
C	TV camera setup	$ 10,000
D	5 Mhz line for TV raster transmission	$ 600[1]
E	2000 bps line for character transmission	$ 60[1]
F	5 MHz line on time shared basis	$ 200[1]
G	TV-raster user terminal without storage	$ 300
H	User-terminal with local character storage using magnetic core	$ 1,500
I.	User terminal with local storage of raster using magnetic disc	Uncertain. Probability 0.2 that can be produced for $600. Probability 0.8 that cost will be $1,000.

[1] These are hypothetical costs expressed on a per user per year basis, assuming an average user-to-central data file distance and an average usage that is independent of the number of users.

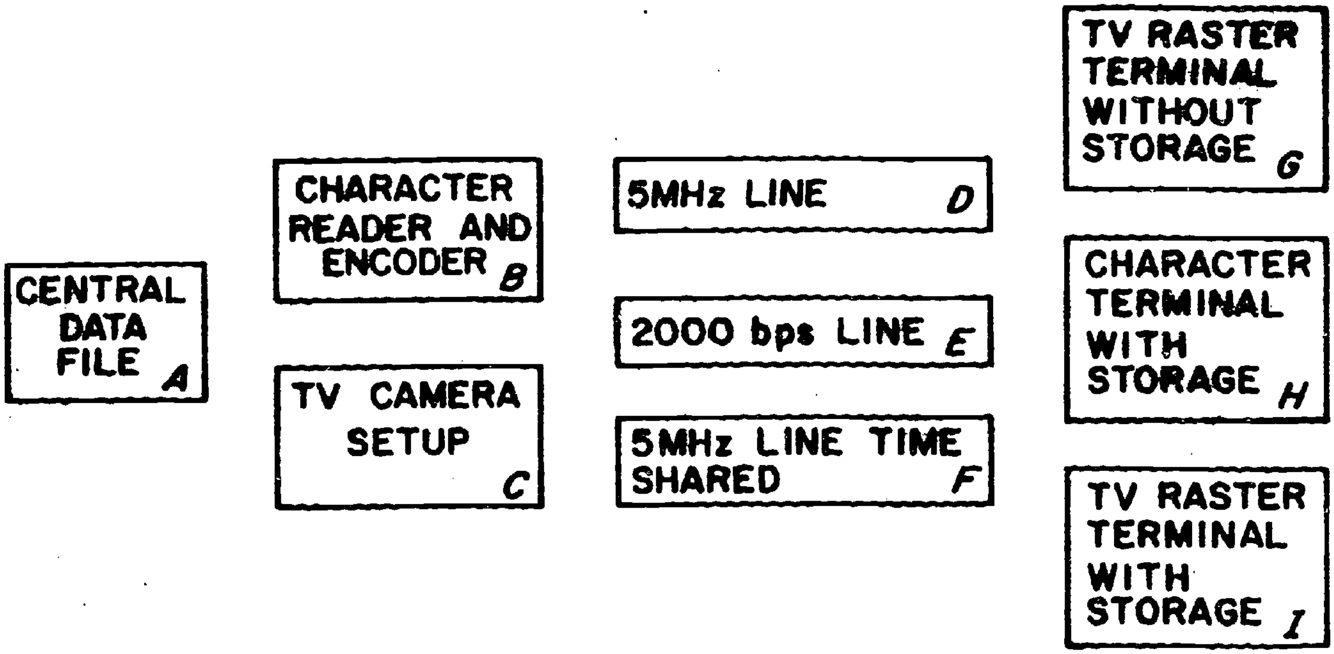
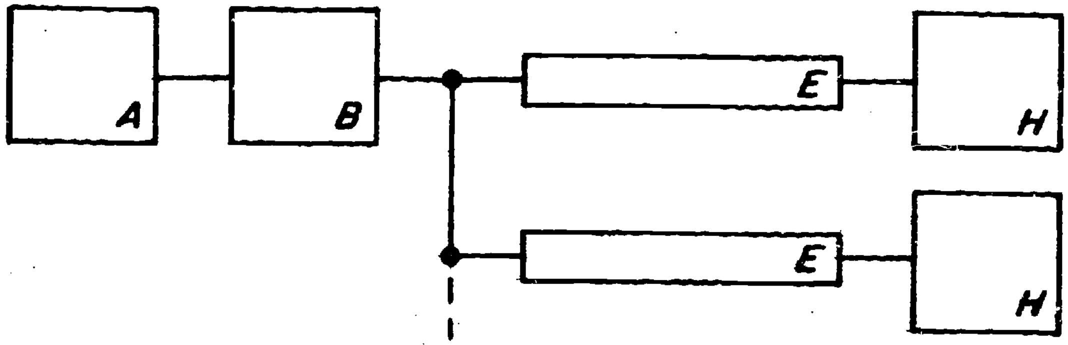
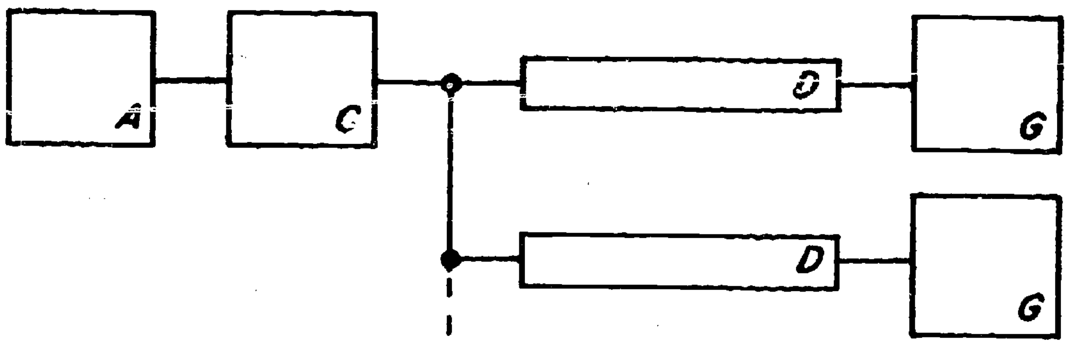


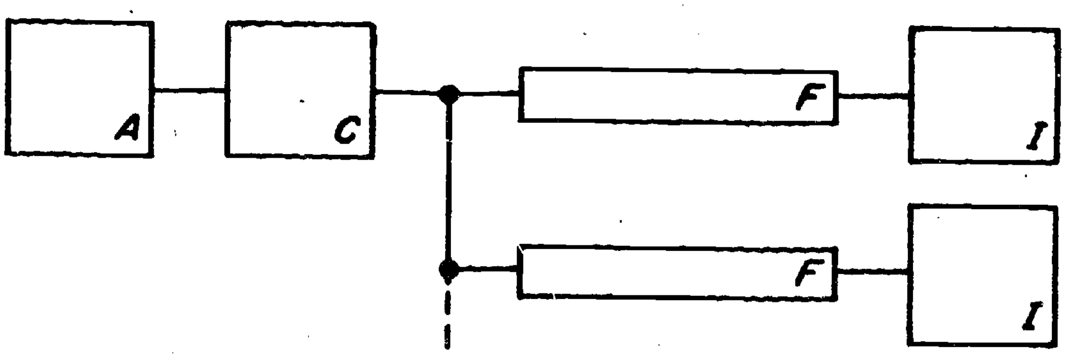
Fig. 2 System components for library systems.



(a) SYSTEM 1 C_{1000} = \$710 C_{10000} = \$462



(b) SYSTEM 2 C_{1000} = \$928 C_{10000} = \$700



(c) SYSTEM 3 C_{1000} = \$602 or 700 C_{10000} = \$375 or 475

Fig. 3. Three hypothetical library systems:
(a) System 1 uses high cost terminals and low cost lines. Costs are for 1000 and 10,000 user systems.
(b) System 2 uses high cost lines and low cost terminals.
(c) System 3 uses intermediate cost lines and intermediate cost terminals requiring a development program with an uncertain outcome.

total system costs. We will consider two cases, a system with 1000 users and one with 10,000 users, and it is assumed that the central data file is adequate to serve the larger number of users. It is convenient to express all costs on a per user per year basis which requires that hardware costs be converted from initial total values to annual values. The maintenance costs, life, and interest rate are assumed to be such that the conversion is on a 4 to 1 basis, i.e. the initial costs in Table 1 are 4 times the annual costs. We also assume that maintenance costs for the are included in the costs listed in Table 1 which are already on a per user year basis.

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[2]The simplest way to think of this annual cost is that this is the price that the decision maker would have to pay to lease rather than buy, because it includes all the factors of cost, including maintenance and capital costs. If we take the position of the owner of the equipment who wishes to lease the equipment to the decision maker, we can calculate our total annual cost as follows [11].

Assume: life = N years

interest rate = i% per annum

maintenance = m% per annum

$$\text{Annual cost} = [\text{First cost}]\left[\frac{m}{100} + \frac{i/100}{1 - \dfrac{1}{(1 + i/100)^N}}\right] \qquad (1)$$

For example: N = 10

i = 8

m = 10

Annual cost = [First cost][0.25]

which is the ratio used in the example here.

Alternative System 1

Character coding, transmission using 2 kbps line

Components A, B, E, H

C_{1000}[3] = \$710 per user (including \$60 line costs)

C_{10000}[3] = \$462 per user (including \$60 line costs)

Alternative System 2

TV raster, transmission using 5 MHz line

Components A, C, D, G

C_{1000} = \$928 per user (including \$600 line costs)

C_{10000} = \$700 per user (including \$600 line costs)

Alternative System 3

TV raster, transmission using 2 kbps line and local storage

Components A, C, F, I

C_{1000} = \$602 per user, with probability 0.2 (including \$200 line costs)

= \$700 per user, with probability 0.8 (including \$200 line costs)

C_{10000} = \$375 per user, with probability 0.2 (including \$200 line costs)

= \$475 per user, with probability 0.8 (including \$200 line costs)

[3] C_{1000} = annual cost for case of 1000 users, C_{10000} = annual cost for case of 10,000 users

Note that the terminal costs for System 2 are much less than those for System 1, but the total cost for System 1 is lower. If we regard both systems as having the same performance, the choice is clear as between these two systems. However, System 2 has a potential performance that could be more useful than System 1, if it were later desired to convert the central data file to one that stored diagrams and photographs or pages of printed text with different type sizes and styles. In order to simplify the comparison, it was assumed here that all data was printed text stored in characters of the same size and style. If this were not the case, but if the data were still only printed text, it would still be possible to make a system comparison, but the character reader and coder would be much more expensive and it is possible that in this case System 2 would be the lower cost system.

System 3 is the lowest cost system for 1000 users, without regard to which terminal design ultimately is developed. If the decision maker does not have to share in the development costs and can delay purchase of his system until System 3 is available, it is a clear choice for a 1000 user system. If the system must serve 10,000 users the problem is more complex. Only if the lowest cost terminal is the result of the development program will this system be lower cost than System 1. If the higher cost terminal is the one that proves feasible, System 1 is lower cost than System 3. How should the decision maker choose between Systems 1 and 3, assuming that he must make up his mind before the terminal development program is complete?

A VALUE PROBLEM

It is helpful in visualizing problems involving probabilistic outcomes to make use of a "decision tree" as illustrated in Figure 4. The cross is a "decision node" at which the decision between systems 1 and 3 is made. The circle is a "chance node" at which the outcome can be either of the costs shown, $375 or $475 per user, each with the probability indicated. These probability estimates are those of the decision maker in the light of all the information that he has available. The solution of such problems is the purpose of decision analysis [1]-[5].

There are two basic steps necessary to the solution of such a problem. First, the decision maker must make probability assessments like those expressed in Figure 4. Second, he must provide a fairly precise indication of how he values the various possible outcomes. The way this is most conveniently done in general is in the form of a utility function. If there were many dimensions to the outcome, he would have to give us his utility when confronted with tradeoffs among all of these dimensions. In the present problem all that is involved is the single dimension of dollars of cost. But there is still an issue as to how highly the decision maker values dollars in various quantities. What is needed is a curve of utility (in arbitrary units) as a function of dollars.

Figure 5 shows two such curves. The meaning of these curves can be made more clear, if we interpret them in terms of "lotteries." A lottery is a situation like that of Figure 4 in which the decision maker selects System 3. He then obtains the lottery: with probability 0.2 his cost will be $375; with probability 0.8 his cost will be $475. An important thing about a lottery is its certain equivalent, i.e. the amount that the decision maker would be willing to pay for sure and be indifferent as to whether he

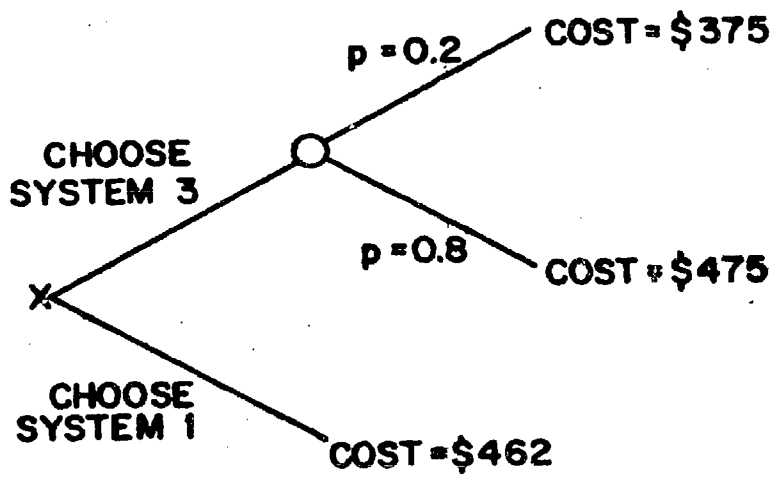

Fig. 4 A decision tree describing the decision between the alternatives of Systems 1 and 3, assuming performance of both systems is identical. A value issue is posed between the uncertain outcome of choosing System 3 and the certain outcome associated with choosing System 1.

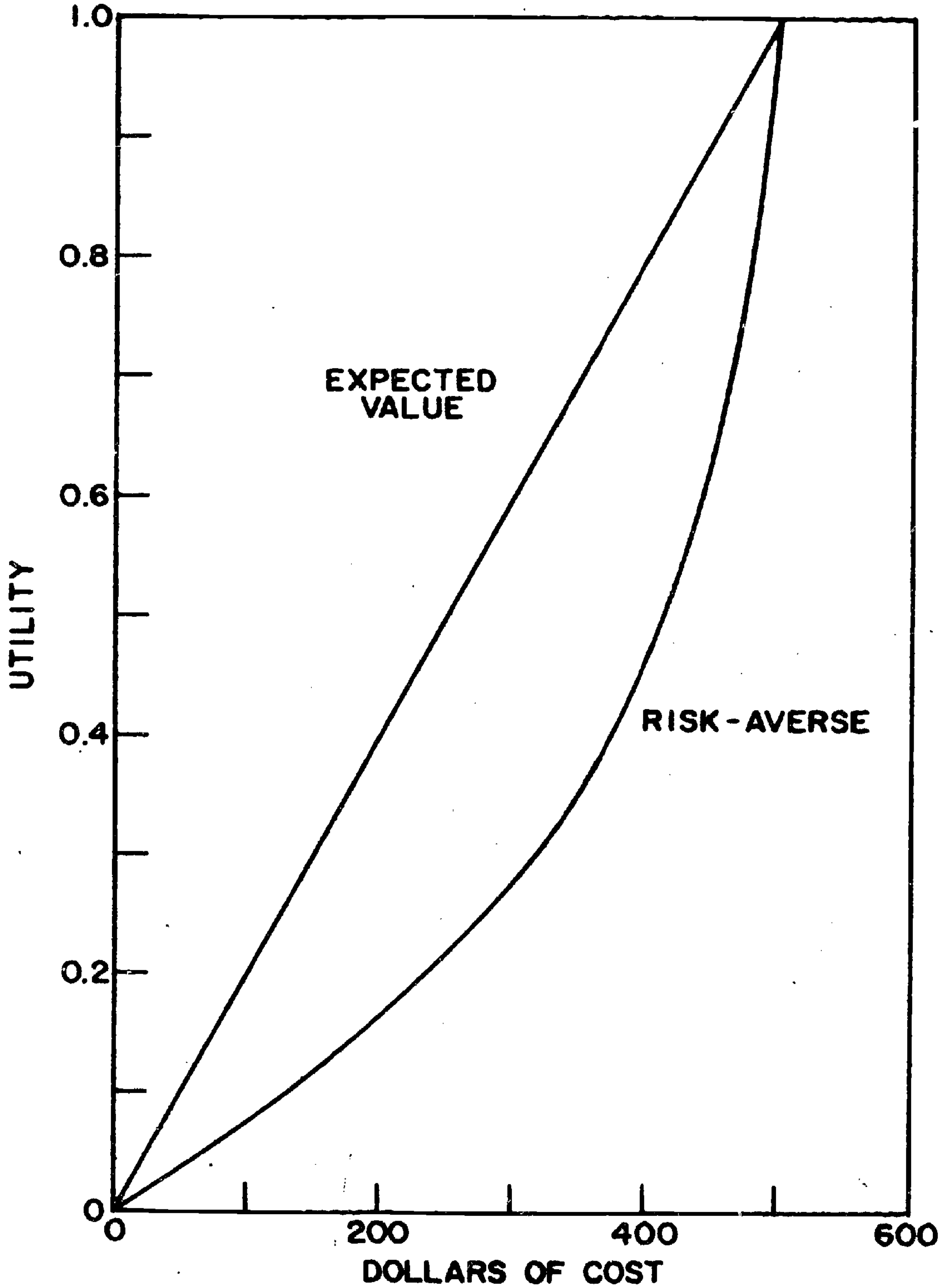

Fig. 5. Utility as a function of dollars of cost for two types of decision makers, an expected-value decision maker and a risk-averse decision maker. If there were an expectation of gain rather than loss, the curve for the risk-averse decision maker would lie above the curve for the expected-value decision maker.

paid this amount or the amount determined from the lottery. If this certain equivalent in our example turns out to be less than $462, then the decision maker should choose System 3. If it is greater than $462, he should choose System 1.

In the curves of Figure 5 the interpretation that may be made in terms of lotteries is as follows. We can assign an arbitrary value of utility to a cost of $500, such as 1.0. Now we ask what is the maximum amount that the decision maker would pay to avoid a lottery in which a fair coin would be flipped and he would pay $500 if it came up heads and $0 if it came up tails. The expected-value[1] decision maker would pay exactly $250 to avoid this lottery while the risk-averse decision maker in Figure 5 would pay more than this amount. The expected-value decision maker is indifferent to risk. The risk-averse decision maker is less inclined to take fair gambles as the stakes become large in comparison with his total resources. Thus we all might be willing to match pennies, but only a few of us enjoy matching hundred dollar bills, even though the game is fair. The risk-averse decision maker in Figure 5 is pictured as a person or organization that is quite sensitive to cost in the vicinity of $400 per user. He is not willing to gamble very much in the hope of getting the cost per user down to $375, as long as there is a risk he may have to pay $475 if things turn out badly.

Once we know the decision maker's utility curve we can insert his utility for each outcome and the probability of this outcome occurring in the following equation [2].

$$u(c) = p(a)u(a) + p(b)u(b) \qquad (2)$$

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[1]The expected value of an uncertain reward is defined as the probability of receiving the reward times the amount of the reward.

where

u(c) = utility of the certain equivalent of the lottery in which a is received with probability p(a) and b is received with probability p(b). p(b) = 1-p(a)

u(a) = utility of receiving a with certainty

u(b) = utility of receiving b with certainty

In our problem, for the expected value decision maker in Figure 5

$$u(a) = 0.95$$
$$p(a) = 0.8$$
$$u(b) = 0.75$$
$$p(b) = 0.2$$
$$u(c) = 0.91$$
$$c = \$455$$

so he would prefer System 3. The risk-averse decision maker on the other hand has

$$u(a) = 0.77$$
$$p(a) = 0.8$$
$$u(b) = 0.4$$
$$p(b) = 0.2$$
$$u(c) = 0.70$$
$$c = \$462$$

This certain equivalent is just equal to the cost of System 1, so he would be indifferent between Systems 1 and 3. Thus, the risk-averse decision maker would pay slightly more than the expected value decision maker to avoid the lottery associated with System 3, but in this case he would be unable to decide between the two systems on this basis alone. In such a case, he might re-examine his probability assessments and also re-examine the assumption that the two systems would have identical performance. As noted previously, System 3 seems to have more potential for the future, if there were any likelihood that the system might be used for diagrams and photographs at a later date. Another variable in this decision problem was the number of user terminals, assumed here to be known with certainty. In an actual problem the number of user terminals would be a function of predicted demand. It would be known only probabilistically, and as we have seen it clearly affects the decision.

In this, and in almost every decision problem, there is at least one variable that can only be known within broad limits. In such cases the issue arises as to whether or not more information should be gathered. More information always comes with a price tag, and so we must have some measure of the value of information, if we are to make a logical choice as to whether or not to gather it. Decision analysis can give a very precise answer to such questions by tracing through the effect that having more information would have on the decision. This process can be carried out by assuming that perfect information is available and examining the cost savings that might result in the best possible case, thus establishing an upper bound on how much it would make sense to pay for perfect information. Of course, we can't normally get perfect information, so we also may need to know the value of imperfect information. A typical example is the kind of information obtained by sampling opinion or testing quality by random sampling of a large lot of some manufactured good. In the references cited [12]-[14] problems of this type are examined in detail.

CONCLUSION

In decisions involving large sums of money, such as the decision of whether or not to invest in an interactive library system and if so, which kind of system, it is worth carrying out an extensive analysis of the alternatives. In this paper it has only been possible to introduce the decision analysis methodology that I believe is well suited to this type of problem. Extensive work has been done in this field, however, and the references cited can lead the reader to more comprehensive presentations. As a rough rule of thumb it is probably worth investing of the order of 1 percent of the amount of money at stake in analyzing the decision. Thus a 1 million dollar decision is worth examining to the extent of around 10 thousand dollars, which is about the threshold at which a meaningful decision analysis can be carried out.

We have seen that the choice of alternatives to be examined is a critical feature of the analysis. It is extremely important in a real analysis, as distinguished from the hypothetical problem described here, that the technical alternatives be very carefully delineated in such a way that the systems being compared have their performance and costs described in the same way. It probably would not be possible to compare system alternatives with the same performance, as was done here. If the alternatives have different performance, we must get into a much more extensive discussion with the decision maker about his preferences than was the case here. Again, the methodology exists for dealing with such problems [15], [16], but a further investment of time is required to carry out the analysis in such cases. In particular the problem becomes much more complex when different alternatives are likely to lead to different behavioral responses by the users. In this case it is at the very least, unwise, to rely on purely technical advice to determine the probable outcomes associated with each alternative.

Another element of a real decision problem that was only hinted at here has to do with the time dimension. Technology is always changing and the costs that are estimated today are likely to be wrong a year from now. Especially is this a problem when we are seeking to compare changing technologies. Technology changes in steps, not in a continuous manner. Therefore, if we compare three quite different technologies in Systems 1, 2, and 3, we are almost certainly comparing yesterday's technology in System 1 with today's technology in System 2 with tomorrow's technology in System 3. Consequently, about the time we install System 3, an improved version of System 1 is likely to be along which is a jump ahead of System 3. The only answer to this issue and to other technical problems of this type that I am aware of is to get the best possible technical advice, both from advocates of particular technologies and from independent sources, and to do a careful planning job that includes as much of this information as possible within the planning budget that is available.

In summary, a good job of planning requires a combination of three functions: (1) decision analysis; (2) technical analysis; and (3) behavioral analysis. Decision analysis provides the analytical framework; technical analysis provides the alternatives and describes the technical outcomes, and behavorial analysis describes the behavioral outcomes. Finally, direct interaction with the decision maker, both early in the planning process and at the time of the decision seems to be essential to a good decision.

REFERENCES

1. Howard, R. A., "Value of Information Lotteries," IEEE Trans. Systems Science and Cybernetics, SSC-3:54-60 (June 1967).

2. North, W., "A Tutorial Introduction to Decision Theory," (Special Issue on Decision Analysis) IEEE Trans. Systems Science and Cybernetics, SSC-4:200-210 (Sept. 1968).

3. Raiffa, R., Decision Analysis, Reading: Addison-Wesley, 1968.

4. Tribus, M., Rational Descriptions, Decisions, and Designs, New York: Pergamon, 1969.

5. Raiffa, H., and Schlaifer, R., Applied Statistical Decision Theory, Cambridge: Harvard Press, 1961.

6. Hamsher, D. H., ed., Communication System Engineering Handbook, New York: McGraw-Hill, 1967.

7. Stimler, S., Real-time Data-processing Systems, New York: McGraw-Hill, 1969.

8. Martin, J., Telecommunications and the Computer, New Jersey: Prentice-Hall, 1969.

9. ---, Teleprocessing Network Organization, New Jersey: Prentice-Hall, 1970.

10. Parker, E. B., "Technological Change and the Mass Media," Conference on Information Utilities and Social Choice, University of Chicago, (Dec. 1969), and also Chicago: Rand McNally, Handbook of Communication, (to be published).

11. Grant, E. L., and Ireson, W. G., Principles of Engineering Economy, 5th Ed., New York: Ronald Press, 1970.

12. Howard, R. A., "Bayesian Decision Models for System Engineering," IEEE Trans. Systems Science and Cybernetics, SSC-1:36-40 (Nov. 1965).

13. ---, "Information Value Theory," IEEE Trans. Systems Science and Cybernetics, SSC-2:22-26 (Aug. 1966).

14. ---, "Value of Information Lotteries," IEEE Trans. Systems Science and Cybernetics, SSC-3:54-60 (June 1967).

15. Fishburn, P. C., "Additivity in Utility Theory with Denumerable Product Sets," Econometrica, 34:500-503 (1964).

16. Raiffa, H., "Preferences for Multi-Attributed Alternatives," Memorandum RM5868-DOT/RC, RAND Corp., Santa Monica, Calif. (April 1969).

FIGURE CAPTIONS

Figure

1 A model of the decision process. The decision process can be viewed as a choice among several alternatives on the basis of the decision maker's preferences for the predicted set of outcomes associated with each alternative.

2 System components for library systems.

3 Three hypothetical library systems:

(a) System 1 uses high cost terminals and low cost lines. Costs are for 1000 and 10,000 user systems.

(b) System 2 uses high cost lines and low cost terminals.

(c) System 3 uses intermediate cost lines and intermediate cost terminals requiring a development program with an uncertain outcome.

4 A decision tree describing the decision between the alternatives of Systems 1 and 3, assuming performance of both systems is identical. A value issue is posed between the uncertain outcome of choosing System 3 and the certain outcome associated with choosing System 1.

5 Utility as a function of dollars of cost for two types of decision makers, an expected-value decision maker and a risk-averse decision maker. If there were an expectation of gain rather than loss, the curve for the risk-averse decision maker would lie above the curve for the expected-value decision maker.