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Application of Systems Analysis

in Designing a New System

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MODERN SYSTEMS ANALYSIS was conceived and born in the computer field. All computers depend on detailed instructions at the elementary level. Machines built before the mid-1950s had no internal programming aids, so the programmer was forced to think and work at this same elementary level. Even the simplest problem was prone to error as it was being planned and coded. Programmers naturally looked for tools and techniques that would reduce this error rate; they called this collection of tools and techniques "systems analysis."

Others, particularly industrial engineers, saw the similarity between their own "efficiency" tools and systems analysis, which they adopted and expanded into noncomputer areas. Systems analysis evolved into the analysis, design, evaluation, and control of complex systems. However, engineers restricted its development to the scientific method. By the early 1960s it had become an engineering discipline.

During this period, the library profession began to feel the need for new tools and techniques to control its growth. This was especially true in the universities. Dix's description[1] of university libraries during the two decades following 1950 clearly shows the need for new management tools. The newness of systems analysis and the special nature of librarianship provided a unique opportunity for material enrichment as the two fields began to come together. Librarianship cuts across many fields, but it saw itself as a humanistic or behavioral science. Systems analysis as developed by engineers was a natural science.

The library profession had a choice: it could have accepted systems analysis simply as an engineering discipline and applied it to that narrow range of engineering-oriented library problems; or it could

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have looked at the fundamental properties of both disciplines and then expanded each to include properties of the other. The first option would have left both untouched; the second would have caused changes in the basic nature of both.

The first option was selected. Librarianship has not changed as a result of using this new tool, and it has contributed little to the development of systems analysis. In fact, systems analysis has suffered because its development beyond engineering type problems has been very slow. Librarianship, a field of many disciplines, could have done much to make systems analysis a field of many disciplines.

This limited use of systems analysis has not been all bad. In fact it has given the profession a chance to accumulate some much needed data about itself. Items listed in the Additional References are rich in this kind of data; they are noted as merely a sample of studies that have been reported. Useful items can also be found in library periodicals and technical reports.

Although we may not have yet reached the peak in applying systems analysis to library problems, we may be rapidly approaching a point of diminishing returns. How many dissertations in the 1970s will repeat Ben-Ami Lipetz's excellent study of the Yale catalog, merely adding another decimal place to what he has already said?

There is little need to write about procedures now being used in library systems analysis. Many of these are discussed elsewhere in this issue. Some general handbooks[2] cover the techniques rather well as do the citations noted in the Additional References. Instead, one should focus attention on underlying principles and implicit processes used by analysts, concentrating on the role of the analyst in the inquiry process.

INTELLECTUAL LEVELS

The human mind works at many levels. The mechanical semiconscious level is used when operating a piece of familiar equipment. Creativity and abstract thinking are needed to contemplate the existence of God and man's reason for being. Man has recognized these levels and has designed many of this activities accordingly. Educational systems, job classifications and levels of authority tend to fall into intellectual level categories. Systems analysis is no exception. It is found among the activities on the academic level. This section will be a discussion of this level, so as to gain some understanding of the way analysts think in their day-to-day work.

Professional practice and academic study are carried out on three distinct levels—operational, problem-solving and philosophical. These tend to correlate with the three basic degree programs—baccalaureate, masters, and doctoral. The person who has completed the first level is expected to have an understanding of the tools and techniques needed to keep the profession in a stable operating mode. He is expected to creatively apply established rules, procedures, theories and laws to the discipline, to keep it functioning at its present level.

Operational level thinking is almost always taught at the undergraduate level. Librarianship is an obvious exception. When librarianship moved up to a masters program, the courses simply moved up. The academic void at the undergraduate level was supposed to have been filled by the liberal arts program.

There has been an increasing concern for some years over this form of library education. The new ALA policy on education and manpower is an attempt to adjust present practices in the direction of other disciplines.

This inconsistency has also had an effect on library systems analysis. The basic tools and techniques of systems analysis (at the operational level) are common to all disciplines. These are taught by other disciplines, especially industrial engineering, at the undergraduate level. Library educators, on the other hand, are being forced to teach the same things at the graduate level. The fact that library systems analysis training is taught at the wrong level does not mean that analysts only think at the lower level. Indeed, they are forced to think at the problem-solving level whether or not they have been trained to do so.

The problem solver can be described as one who creatively applies basic principles to the solution of problems. He is the one who questions current operating procedures and attempts to make significant changes or improvements in those procedures. He is the one who designs new systems. As a corollary to these analytic and synthetic activities, he develops and runs evaluation and controls subsystems. He is a practical person with a questioning mind. He is reluctant to accept the discipline's current status as either good or adequate. Yet he is not trained to question the philosophical foundations of the discipline.

A person at the third level is trained to question the very foundation of the discipline. One such question in librarianship might be, "Does the static nature of recorded information and the dynamic

nature of knowledge lead to an unbridgeable gap in classification theory objectives and classification practice?" Although this question might be motivated by day-to-day problems, its answers are likely to be philosophical.

The system analyst, when working as a professional person, is in the second category. The way problems are defined, tools selected and value judgments made, sets him apart from both the operational and philosophical levels, and from other professions working on the same problems. He may, indeed, spend much of his time doing routine data gathering and synthesis, but his professional work occurs at this higher level.

It should be noted that the intellectual levels and academic categories as described are consistent with the ALA policy on education and manpower and two statements from the Council of Graduate Schools in the United States.[3] Librarianship as taught and practiced today must fall in line with these levels if it is to integrate and use other disciplines, such as systems analysis.

RESEARCH METHODOLOGY

The scientific method of finding truth has so dominated inquiry methodologies since the renaissance that the word "research" has become synonymous with the "natural scientific method." Yet mathematics, the behavioral sciences and the humanities have their own methods, and within each group there are modifications and borrowings from others.

Librarianship is a very broad discipline that has characteristics in common with almost every other field. In fact, it is so broad and its parts are so closely related to other fields that it does not have a methodology of its own. The systems analyst, if he expects to address the problems of librarianship, must be able to work within these many methodologies. His traditional industrial engineering or natural science background is not enough. This section is a review of some of the more common research methodologies that the analyst must know well.

Let us begin with the assumption that research is the directed search for truth. By "directed" I mean that the investigator begins his inquiry with selected first principles, procedures and value judgment standards. He accepts the fact that the end result of his inquiry will be a function of his selection. In other words truth is not absolute. It is relative to the assumptions made.

Churchman has recently written an excellent analysis of some classical inquiry methodologies.[4] The discussion that follows borrows freely from his book. The deductive or axiomatic method, referred to by Churchman as the Leibnitzian method, is based on the belief that first principles are innate to the human mind. By identifying these principles we can build valid systems. Mathematics is the simplest example: the theoretician or working mathematician begins with the understanding that certain principles (he calls them axioms or postulates) are known without proof. For example, Euclid identified a set of postulates on which he built his geometry. The truth of the geometry is accepted because the postulates are "known" to be true and the rest of the system is consistent with them.

Yet there was a flaw in the system. In 1841 Lobachevski simply ignored Euclid's fifth postulate concerning parallel lines and substituted another. The result was a new geometry internally consistent but contradicting some Euclidian theorems. Mathematics eventually gave up the idea that absolute truth was possible and is now content to begin all inquiries with "If such and such is true then. . . ."

The natural scientist is in a similar position. He begins with the belief that truth is to be found by observing the event world. He relies on the consensus of his colleagues to guarantee this truth. The scientist also has his limits. Many things do not lend themselves to observation, and contradictions abound.

The legal profession is a good example of a third method. Truth concerning a defendant's guilt is determined by the dichotomy established between the defense and prosecuting lawyers. Here all parties assume that truth (or a close approximation to it) will result from the fight between diametrically opposed positions. Churchman uses the philosophy of Hegel to develop this method.

Two methods not considered by Churchman, yet vital to librarianship, are the evolution and humanistic methods. Whereas the others begin with static assumptions, the evolutionist says that truth is a dynamic, continuously evolving entity. Hence truth is a function of time and absolute truth is beyond time. Teilhard de Chardin must be acknowledged for his work in this area.[5]

The humanist also must be acknowledged. He believes that truth is a function of the individual. He would not deny contributions from others, but he would insist that each individual be free to place his own value judgments, or emphasis, on the factors he uses in his search for truth. The unspecifiable personal emotion is fundamental

to the humanist. A recent work by Bernard Lonergan[6] develops this approach and D. E. Berlyne[7] has attempted to analyze the method.

"Participative observation," used so successfully by sociologists and cultural anthropologists, must also be mentioned because of its relevance to librarianship. Here the researcher assumes that he must become personally involved in the experiment itself if he is to find truth. Here the researcher observes as the scientist does, but he also becomes a part of the thing being observed so he can better evaluate its true meaning. Hopefully he has selected a perspective that will permit him to generalize on his observations.[8]

Librarianship is a phenomenon which lends itself to investigation by all of these methods. It is also a holistic phenomenon, i.e., the parts of librarianship cannot be separated or divided into disjointed, noninfluencing parts without significantly influencing its truth value. This, of course, complicates the problem for the analyst. He must have a broad perspective and then select the methods that will give him, in his estimation, the closest approximation to truth. Indeed, the selection of methods is one of his most professional duties.

The time has come to recognize this broader interest and role of the systems analyst. He can no longer be considered as an engineer or natural scientist. Actually the transition can be quite simple if we focus attention on basic concepts and not on his tools and techniques. The new ALA Office for Research can also do much to bring this about. Its leaders need only to broaden their view of research beyond the scientific method.

RESEARCH AND DEVELOPMENT SPECTRUM

This inquiry process has another face. It is also a spectrum of activity beginning with a concept and progressing through research, development and implementation to the final operation. Specific problems can be placed along this spectrum. The tools, techniques, methods, and value judgments used by the analyst will be determined by the nature of the problem and its place on the spectrum. Let us, therefore, look a little deeper into the spectrum's characteristics.

Two initial observations should be made. The inquiry process is called a spectrum because there is a sequence or hierarchy to the process, and there are no clearcut boundaries or mileposts between major sections. The analyst always passes through all sections up to the place on the spectrum where the problem is to be found. He may unconsciously reject the earlier steps; however an element of accep-

tance is always present. I will therefore describe each section as though the analyst were emphasizing that part.

When the initial problem is presented to the analyst, he searches through possible solutions and approaches to solutions. These are rarely well defined, just as the problem itself is rarely well defined. The initial step is to formally define the problem and possible solutions. This is the concept phase.

The next step is to determine feasibility. This is the principal objective of the research phase. Here the concern is not to find an efficient, best, or most acceptable solution. Rather the analyst wants to answer the question, "Is any solution possible, or which solutions are possible?" For example, the analyst may be designing the bibliographic citation that is to appear on a display terminal and determine the speed at which this citation is to be displayed on the screen. The solution to his problem is only possible within the physiological and psychological boundaries of humans as determined by experimental psychologists.

Sometimes feasibility is not so clearcut. It may be mathematically possible for a small college to use a $1 million book budget in one year, but in practice very little analysis would be needed to show that chaos would result if the school tried to spend it.

This is the phase that is commonly related to the theorist or scientist. He may use specifications, standards, and detailed data; however, these are only aids to help determine feasibility. In this phase, although the analyst has the final responsibility, he may call upon experts to provide information from which he makes value judgments and decisions.

The result of this feasibility effort is usually a redefinition of the problem and the elimination of impossible or poor solutions. The project then proceeds to the next phase with an increased probability of success.

The data and specifications from the research phase may or may not be carried over into the development phase. Here the objective is to take the possible solutions from the researcher and convert them into firm specifications or blueprints of the final solution. This is the area where the architect, engineer, and analyst are in almost total control. "Feasibility" is replaced by terms such as "acceptability" and "efficiency." Simulations, models and tests are common. Almost all the tools and techniques used by analysts today are used by them in this developmental phase.

Developmental projects may require the services of many different kinds of people, yet it is here where the analyst is most likely to be in control. He has the overall vision of the program, and a sensitivity for the tools and techniques used. He is also an expert on the use of project control techniques such as PERT.

The output of this phase is not a finished product or operational system. Rather it is the specification to the person who will actually make the implementation. Again the probability of a successful finished product should be significantly enhanced if the analyst has done his job properly.

I do not see a significant role for the analyst in the implementation phase. The implementation of a solution, especially if it is a large design problem, requires the services of a special kind of person—one more like a building contractor than a designer or analyst.

The end of the spectrum is the steady state operation. Here the idea is to avoid change, avoid problems, and maintain stability. Again the analyst plays a role in this phase. It is he who designs and runs the management information subsystem that provides data for the operator's evaluation and control. The details of this activity will be discussed in the following section.

TOOLS AND TECHNIQUES

So far I have emphasized the analyst's intellectual working levels and decision-making activities. This section will return to the four basic activities of systems analysis—analysis, design, evaluation and control—and emphasize the tools and techniques to be used.

Analysis—Analysis of an existing operation usually begins with the development of a clear understanding of the function and purpose of the operation or problem. Function and purpose determine the tools, techniques and value judgments to be used in the analytic process.

The need for the "clear understanding" cannot be overemphasized. The analyst, management, and operations personnel must all be in agreement about both the nature of the operation itself and the nature of the analyst's assignment. Failure to give adequate attention to this factor frequently results in one of the analyst's worst sins—solving the wrong problem.

The next task is to determine the depth to which he is to perform the analysis. Is this a study to give management an overview, or is

it to improve efficiency at the individual task level? Are there measurement tools available that will provide meaningful data at the level desired? These are the kinds of questions that help the analyst determine the proper level of depth.

Flow analysis itself usually begins with the identification and separation of the operation into meaningful parts. Again it is function, goals and depth that determine what is meaningful. These parts are then linked together (usually graphically) to give the analyst an accurate picture of the operation. This whole process is called flow charting. The completed flow chart is then examined for things such as dead ends, meaningless operations, circular routes, and repeated operations. Each step is checked to see why it exists and to determine if it can be eliminated without affecting the operation. The analyst must also be more than an efficiency expert. A step in an operation may be there only for psychological reasons, yet the operation would collapse without it.

This is also the time when each activity is identified according to its intellectual level. Here the recent ALA policy on education and manpower can be a valuable standard for library analysts.[9] This document provided four levels of library tasks—professional, associate, technical, and clerical. A professional applies creativity to basic principles in the solution of problems. The associate is concerned with the creative application of established rules and techniques. The technician uses his decision-making powers to perform tasks in an efficient manner, and the clerk mechanically performs tasks that require no decision-making ability.

Some tasks lend themselves to quantification (e.g., the average number of keystrokes required to type a book order). The analyst must determine tasks for which quantification will be relevant, the method to be used to gather the data, the degree of accuracy needed, and the probability of biases.

The key word in quantification is "relevance." The lure of numbers, their apparent authoritativeness, their definitiveness and their comparativeness tend to influence analysts to look to quantification whenever numbers can be gathered. This is one activity where a "devil's advocate" can usually temper an analyst's enthusiasm.

Flow charting and quantification are the two basic analytic tools. Two of the more important secondary tools are simulation and the use of standards. Machine specifications, regulations, laws, etc., also enter into the creation of an overall profile of an operation.

Design—The synthesis of design operation is the inverse of analysis. Whereas the analysis activity is an attempt to determine how an operation now works, design is the attempt to create the best possible operation from both existing and new pieces. Whereas analysis tends to be a straightforward dissection activity with little feedback or interaction between parts, design is very much a cybernetic activity.

Design begins with the same steps as analysis—a clear understanding of what is to be designed. Did the analysis change the design criteria? Did the analysis solve the problem? Is the design feasible? Will the desired design give the desired results?

The analyst then searches his repertoire of tools, techniques and facts for an appropriate design process. He will select between a holistic and a modular design. He will choose between unique specifications and standards. Other factors such as cost, complexity, applicability, and maintenance will influence his decisions. As he selects design components, he tests them and fits them into parts of the overall system. Finally he has a working model or blueprint of the final operation. If he has done his work well, he will give the implementor detailed instructions for converting the blueprint into a smooth operation.

Overall design is the responsibility of the systems analyst. There may be specialists from other disciplines working on specific parts, but overall conceptualization, coordination and evaluation is the kind of work he has been trained to do. He sees the broad picture, can make value judgments and knows how to relate the parts to the whole.

Evaluation and Control—Of course evaluation and control occur as part of the analysis and design activities. These are also essential in the final operational phase. There is a need for management aids that will help keep the operation in a stable mode. The subsystem called MIS (Management Information System) brings together the tools, techniques and procedures that serve this function. (I am expanding on the terminology in common use today. Originally MIS referred to computer subsystems—hardware and software—used to gather data about large systems operations. The analyst designs MIS subsystems and plays a part in their operation.

I will begin with a description of an operation. Data about an operation are collected routinely and then fed to the processing operation where it is stored, synthesized, and compared with other data.

It is then fed either directly to management where decisions are made, or to a data evaluation activity.

In the evaluation activity the data are evaluated with respect to four sets of constraints. These are the limits imposed by the operation itself (e.g., space or funds), past data, management decisions or constraints and technical limits (e.g., adequate statistical samples). The evaluated data normally go to management where decisions are made concerning the operation itself. Occasionally the data may be used for direct control. For example, no bills can be paid when funds have been depleted regardless of management's decisions.

The analyst plays two roles in this subsystem: he helps determine the data to be gathered and presented to management, and he is also part of the data evaluation activity.

I have presented the systems analyst as the library profession's problem solver. He has a repertoire of tools and techniques which he has inherited from engineering. His future will depend on a broadening of these tools and techniques into nonscientific applications. The analyst is very much an artist or creative professional. He works from the creative application of basis principles—not formulas.

References

1. Dix, William S. "Two Decisive Decades: Cause & Effect on University Libraries," *American Libraries,* 3:725-31, July-Aug. 1972.

2. Bocchino, William A. *Management Information Systems: Tools and Techniques.* Englewood Cliffs, N.J. Prentice-Hall, 1972; Iveson, W. Grant, ed. *Handbook of Industrial Engineering and Management.* Englewood Cliffs, N.J., Prentice-Hall, 1971; and Machol, Robert E., ed. *Systems Engineering Handbook.* New York, McGraw-Hill, 1965.

3. American Library Association. *ALA Policy on Education and Manpower.* Chicago, ALA, 1970; The Council of Graduate Schools in the United States. *The Masters Program: A Statement by the Council.* Washington, D.C., 1968; and ——————. *The Doctor of Philosophy Degree.* Washington, D.C., 1969.

4. Churchman, C. West. *The Design of Inquiring Systems: Basic Concepts of Systems and Organization.* New York, Basic Books, 1971.

5. Teilhard de Chardin, Pierre. *The Phenomenon of Man.* New York, Harper, 1959.

6. Lonergan, Bernard J. F. *Insight; A Study of Human Understanding.* 3d ed. New York, Philosophical Library, 1970.

7. Berlyne, D. E. *Aesthetics and Psychobiology.* New York, Appleton-Century-Crofts, 1971.

8. Pelto, Pertti J. *Anthropological Research; The Structure of Inquiry.* New York, Harper & Row, 1970.

9. American Library Association, *op. cit.*

ADDITIONAL REFERENCES

Burkhalter, Barton R., ed. *Case Studies in Systems Analysis in a University Library.* Metuchen, N.J., Scarecrow Press, 1968.

Dolby, J. L., *et al. Computerized Library Catalogs: Their Growth, Cost, and Utility.* Cambridge, Mass., M.I.T. Press, 1969.

Gimbel, Henning. *Work Simplification in Danish Public Libraries: Report of the Work Simplification Committee of the Danish Library Association* (LTP Publication, no. 15). Rudolph C. Ellsworth, trans. Chicago, Library Technology Program, ALA, 1969.

Lipetz, Ben-Ami. "Catalog Use in a Large Research Library," *Library Quarterly,* 42:129-39, Jan. 1972.

Leonard, Lawrence E., *et al. Centralized Book Processing; A Feasibility Study Based on Colorado Academic Libraries.* Metuchen, N.J., Scarecrow Press, 1969.

Morse, Philip M. *Library Effectiveness: A Systems Approach.* Cambridge, Mass., M.I.T. Press, 1968.

Palmer, Richard P. *Computerizing the Card Catalog in the University Library: A Survey of User Requirements.* Littleton, Colo., Libraries Unlimited, 1972.

Raffel, Jeffrey A., and Shishko, Robert. *Systematic Analysis of University Libraries: An Application of Cost-Benefit Analysis to the M.I.T. Libraries.* Cambridge, Mass., M.I.T. Press, 1969.