THE APPLICATION OF STRUCTURED SYSTEMS ANALYSIS TO THE DEVELOPMENT OF AN AUTOMATED MAPPING SYSTEM

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ABSTRACT

In many cases, automated mapping systems seem to have been designed and acquired without due regard for their intended use. A structured, systematic approach, however, increases the chances of successfully implementing such a system. This paper focuses on how the Mapping Services Branch and the Computer Systems Development Branch of the Tennessee Valley Authority (TVA) used such a structured approach in conducting the first phase of system acquisition (i.e., a feasibility study).

The use of a commercially available methodology enabled the project team to proceed with the feasibility study in a logical order, starting with the project scope, continuing through problem identification and general system requirements, and ending with a financial analysis of the proposed system. We believe this approach has greatly improved TVA's chances of success in designing, acquiring, and implementing a system for digital photogrammetric-based mapping, map compilation, and revision of 1:24,000 and 1:100,000 national map series topographic quadrangles, cadastral maps, and special-purpose mapping to support such TVA programs as recreation, power, and wind energy.

INTRODUCTION

Since March 1980, the Tennessee Valley Authority* has been involved in the procurement of an automated mapping system to lower the cost of maps produced both for TVA and as part of the National Mapping Program.** To date, a feasibility study, a System Design Manual, and a request for proposals for such a system have been produced. The feasibility study and System Design Manual were prepared using a

*TVA is used in this paper with specific reference to the activities of the Mapping Services Branch and the Computer Systems Development Branch, both in the Division of Natural Resource Operations, Office of Natural Resources.

**Under an agreement with the U.S. Geological Survey, TVA has the responsibility for mapping and maintaining the 775 seven-and-one-half minute quadrangles that lie within the 40,000-square-mile Tennessee Valley. In 1980, the USGS agreed to let TVA produce the 71 metric-base 1:100,000 quadrangles that cover the TVA power service area, an area about twice the size of the watershed. TVA additionally produces and maintains cadastral maps for all of its property holdings, navigation, as well as recreation, and other special-purpose maps to support various TVA programs.

structured system analysis and design methodology called "PRIDE," which stands for "PRofitable Information By DEsign through Phased Planning and Control."* The use of this systems methodology has been required by agency policy for all ADP procurements in TVA since 1976.

Our initial systems development effort (which resulted in a feasibility study) facilitated the subsequent writing of the Request for Proposals. This paper will discuss the activities undertaken using PRIDE to produce a feasibility study for an automated mapping system.

PROJECT SCOPE

The first step we took in the feasibility study was to define the project scope. In order to do this, we looked at what administrative units would be involved and what functions in these units would be affected by the introduction of an automated mapping system.

Our first project scope definition included the Cartographic Section and the Photogrammetry and Remote Sensing Section of the Mapping Services Branch. Cartographic applications to be addressed were the production of 7-1/2 minute topographic quadrangles; metric base 1:100,000 topographic quadrangles, cadastral maps, records, and measurements; and special-purpose maps and graphics. Those photogrammetric applications to be addressed were 7-1/2 minute and large-scale topographic manuscript production, special-purpose mapping and profiles, cross sections, and volumetric computations.

During the feasibility study, the project scope was redefined to include, in the Photogrammetry and Remote Sensing Section, only Valley Topographic (National Mapping Program) Mapping and special-purpose mapping. The Cartographic Section scope remained the same, and a third area, "Management," was added. This last application is intended to be a relatively small part of the Automated Mapping System; it will include such applications as system utilization and map production tracking and reporting.

The project scope was a critical part of the feasibility study; once the study was approved by branch, division, and office management, the project scope was fixed. This has already helped in turning aside requests and ideas for other applications to be put on the system until the applications outlined in the scope have been implemented (i.e., the project scope has been used to avoid being sidetracked from our original purpose).

*"PRIDE" is a proprietary product and registered trademark of M. Bryce & Associates, Inc., Cincinnati, OH 45215.

DOCUMENTATION

The next step in our feasibility study was to document the existing administrative system, workflow, and information needs. (Information needs are the "pieces" or types of information needed for a procedure in the workflow to take place.)

We first assembled the existing organization charts for the Mapping Services Branch. Using the project scope, we then decided which people in which functional areas we wanted to interview. The interviews, conducted with about 15 percent of the branch personnel, clarified the administrative organization and provided a basis for documenting the workflow.

The workflow was best divided into four product-related areas: cadastral maps, 7-1/2 minute quadrangles, 1:100,000 quadrangles and special-purpose maps. Charts were then constructed showing the present flow of each type of map production, and, to check their accuracy, they were reviewed with the people working in those specific areas. The workflow diagrams, in conjunction with our interview notes, enabled us to construct a new set of charts showing the information needs for each procedure defined in the workflows. These charts show each procedure on a separate line, and for each procedure they show the source of the information needed, the actual information needed, the administrative unit requiring the information, the data output as a result of this procedure, and the destination of the data. The data output as a result of one procedure most often becomes the information needed by a subsequent procedure.

Using the information needs charts, we identified those procedures (taking into consideration their information requirements) that were likely candidates for automation. With these procedures identified, we then used our interview notes and workflow diagrams to see which specific workflow problems could be alleviated.

PROBLEM IDENTIFICATION

The activities described above enabled us to identify the following problems that were amenable to automated solutions:

1. Labor intensiveness of the manual system, which has been responsible for the increasing cost of map products.

2. Unfilled requests for new maps or map updates due to production limitations.

3. Lack of flexibility in production; usually only one set of (master) negatives are available for a map. This especially affects special-purpose mapping, which uses common map bases to create many specialized products.

4. Maintenance of redundant data (multiple sets of

map negatives) for maps produced at different scales--especially for special-purpose maps.

5. Large amount of reprographics (shop) work required to produce derived maps (for example, 1:100,000 quads from 1:24,000 quads and nuclear power plant radius maps from 1:100,000 quads).

SYSTEM REQUIREMENTS

Once we knew what the problems were that we had to solve, it became possible for us to set out both general and specific requirements for an automated mapping system.

The general requirements are that the system must be installed (implemented) without affecting current production and that it be compatible insofar as possible with TVA's Geographic Information System and the USGS's digital cartographic program. The system must be able to produce map revisions that meet current accuracy standards more economically than through manual means, and it must be flexible and expandable to incorporate additional applications. Furthermore, it must be able to interface with TVA's central computer.

Specific requirements were then outlined for each type of map production. For cadastral mapping, the elimination of much redrafting that now takes place for successive versions is essential to generate cost savings. Because special-purpose maps are derived from existing map bases, the system must support the selective display, editing, and plotting of data. Data manipulation, such as scale changes, is critical to reducing the presently large amount of shop work on such maps, which in turn will allow a faster map production turnaround time. For 7-1/2 minute and 1:100,000 quadrangles, the system must support the conversion of detailed map data from graphic into digital form, and the interactive editing and plotting of this data while maintaining the accuracy standards of the national map series. Significant cost savings for these maps depend upon high-quality plotting of line work that will eliminate much of the lengthy scribing process. The availability of this data in digital form will additionally provide base map data to support compilation of most of the derived maps we produce and analysis for natural resource planning, most of which will be performed by TVA's Geographic Information System.

These requirements in particular provided a framework that was later helpful in writing a Request for Proposals.

FINANCIAL ANALYSIS

At this point in our feasibility study, we knew what the problems of the system were and how we intended to solve them. This was fine, except for the fact that we had not yet asked ourselves if TVA would ultimately benefit from the project. Clearly, if the benefits (including dollar savings and new capabilities) did not outweigh the costs, the project could not be justified. Our next job, then, was to cost-justify the proposed system. We consulted a TVA economist to be sure that we used a sound method of cost justification. Two major ways of analyzing the costs and benefits of a project were suggested: an economic analysis and a financial analysis. A financial analysis takes inflation into account during the system's useful life,* whereas an economic analysis does not. We were advised that with a labor-saving application such as ours it would be to our advantage to do a financial analysis, since the cost of manual labor will rise faster than will the system's life (10-year) cost of paying for and operating a computer system designed to replace much of the manual labor.

To proceed with a financial analysis, it was necessary to arrive at figures representing initial costs for the system, annual operating costs, benefits to cartographic production, and spinoff benefits to others.

Initial Costs

Since the vendor who would supply our system was unknown, we were able to arrive only at an approximate system cost. This was done by obtaining the prices for all hardware and software modules that would be needed to support our application from a vendor likely to be a strong contender for our contract. To this system cost were added the estimated costs for a high-precision photohead plotter (to be acquired two years after the initial system purchase) and for systems development (estimated by our Computer Systems Development Branch).

Annual Costs

Annual costs consisted of interest and amortization, additional interest and amortization after purchase of the photohead plotter, data base loading, maintenance, and systems support. Interest and amortization for the initial system and for the photohead plotter were taken from standard tables and represent what the borrowed money will actually cost TVA on a yearly basis. Data base loading was based upon the number of workstations and shifts available. With our two initial workstations, we felt we could assign two full shifts to one workstation and one-half shift to the other workstation for data base loading. The related cost was based on an average cost for a workstation operator. This process has been given a high priority, because data must be loaded into the system or be available to the system in digital form before the system can support production. Annual maintenance costs were based on roughly 10 percent of the system purchase price. This seems to be the figure used by most vendors. The need for internal systems support was an estimate based only on projected need.

*The useful life of a system can usually be extended by making modifications to the system.

Benefits to Cartographic Production

The benefits to Mapping Services Branch cartographic production were calculated for the initial system only and for the system with a high-precision photohead plotter. These calculations showed a significant increase in expected savings due to purchase of this plotter after the first two years of operation.

To calculate these benefits, we first had to collect data on the current costs of producing maps manually. Through estimates given by our production people and information extracted from production and cost records, we were able to arrive at the approximate number of hours needed to produce each type of map considered in the study. For the two topographic quadrangle series, however, the number of hours needed for each step in the production of these maps was recorded because of their more complex production flows.

The average wage rate for the people producing these maps was added to shop costs (as a percentage of the total), overhead costs, and benefits, so that the figure would represent TVA's true cost. This wage rate was then multiplied by the number of hours needed for each map (or map production step) to yield a current cost figure for each type of map we produce.

The next activity we undertook was to determine the probable production savings. On the basis of our knowledge of cartography and automated mapping system capabilities, we talked with the same people we had interviewed earlier for time estimates. After having briefly explained some of the capabilities of automated systems, we together arrived at what we felt would be a reasonable figure for either the percentage of time or the number of hours that would be saved using automated methods. These estimated savings were then converted to dollars and subtracted from the manual labor costs to yield automated map production costs.

For all types of mapping except cadastral, we generated two sets of figures for automated production costs: one with the initial configuration (containing only a pen plotter) and one with the high-accuracy photohead plotter. This was done because most of the savings for the topographic map series are based on the reduction of the labor-intensive map finishing process (especially scribing), which can be accomplished only when the photohead plotter is installed. Some extra savings are expected for special-purpose maps because of a reduction in shop work. Significant savings, however, will be possible with just the pen plotter in cadastral and special-purpose mapping because of less stringent production specifications. Additionally, because cadastral maps are produced only in black and white on a single layer of drafting film, there is no need for color proofs or separations.

It should be noted that the calculation of these benefits was based upon the continuation of the existing workload.

As long as the workload remains constant or increases, the benefits will remain valid.

Benefits to Others

Benefits to others represent the value--inside and outside TVA--of the digital cartographic data that will be part of the system. While these benefits are more difficult to document than the benefits to the Mapping Services Branch, they are every bit as real. In most cases, the values of these benefits were determined jointly by us and the people responsible for the areas involved. We feel that our benefit estimates are on the conservative side; actual benefits may turn out to be much greater.

Analysis

After having calculated the initial costs, annual operating costs, and both sets of benefits, we performed our financial analysis to arrive at a benefit/cost ratio for the project. The detailed methodology of this analysis is beyond the scope of this paper; however, it should be noted that inflation and the cost of money to TVA were included as factors affecting the costs and benefits of the proposed system.

PRIDE allows the systems analyst an opportunity to refine the cost/benefit analysis performed in the feasibility study. This analysis is also required in the next phase, the System Design.* Our financial evaluation in the feasibility study yielded benefit-to-cost ratios of 2.2 for internal cartographic production and 2.6 for all users. When we informally repeated the analysis with better and more up-to-date data as part of our Phase II (System Design Manual), we arrived at figures of 2.0 for internal production and 2.4 for all users. One should understand that a financial analysis is a continual process of refinement; the analysis can only be as accurate as the data on which it is based. In PRIDE, the analysis is used as a basis for management approval, modification, or cancellation of a project. If the project is approved, as it was in our case, the true test comes after implementation, during the system audit. Then we will be able to assess the accuracy of our predictions.

SUMMARY

PRIDE, a structured systems methodology has enabled the personnel involved in TVA's Automated Mapping System to see where they are going before the system is purchased. We have defined our five application systems and their major steps, and we know how each system's data will be shared--we know what we have to do to make the system work. By defining the project scope, documenting the existing system, identifying the existing problems, setting out system requirements, and analyzing the costs and benefits

*In the PRIDE methodology, the System Design is the second of nine phases.

of the system, we at TVA have gone into this project with our eyes open. To date, we have received very few surprises and expect fewer than usual during system implementation because of our use of structured systems analysis.

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