SYSTEM DEVELOPMENT METHODOLOGIES AND TOOLS: POSSIBLE INFLUENCES AND IMPLICATIONS

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ABSTRACT

Persons developing computer-based information systems have a variety of basic methodologies and tools from which to choose. What factors possibly influence selection? And, once a methodology or tool is selected, what are its possible influences on the development process or the resultant operational system? A study of computer-using firms in Texas sheds light on these fundamental questions.

INTRODUCTION

Over the past several years various tools and methodologies have been developed to aid the system development process. In the 1960s, systems were developed to solve well-structured problems; stand-alone accounting and transaction processing systems composed the majority of systems. These systems were well defined, simple, and smaller than the systems being developed today. As the number of lines of code and complexity of systems grew and the problems being addressed became less structured (i.e. strategic decision making), the task of developing systems became more difficult. Communication between members of development teams became increasingly difficult due to the large number of persons involved (Brooks, 1975). The traditional project team approach using the monolithic, verbal, functional specification as the primary documentation for system development guidance became unwieldly, and resulted in many unsuccessful and/or uncompleted systems (Yourdan, 1976). The need for new methodologies and tools for systems development was recognized and many different approaches were devised. Some of these approaches were single documentation tools such as Nassi-Schneiderman diagrams and Warnier-Orr diagrams. Some were complete methodologies such as Yourdan's structured approach, or Jackson's methodology (Jackson, 1975). Other approaches included making the retrieval of information available to users via equipment and software modification. This move toward end-user computing often has been accompanied by an information center concept that is designed to aid the end user in utilizing available equipment and software such as database query languages to retrieve information on a demand basis.

TOOLS AND METHODOLOGIES

Some of the development tools and approaches that have been devised during the relatively short period of the computer era include the following:

Systems Flowcharts

Systems flowcharts are system-level graphic charts that illustrate the physical flow (device specific) of information through the system. This tool is part of the traditional approach to analysis and design and has been used for many years. Several of the symbols have been standardized on a national and international basis.

Decision Tables

Decision tables are logic design aids that serve to decompose a complex problem into its component conditions and actions. There are four sections to each decision table; the upper two deal with conditions, and the lower two deal with actions. The strength of the decision table is that all possible conditions and their resultant actions can be taken into consideration.

Data Flow Diagrams

Data flow diagrams (DFDs) are graphical in nature. They present a pictorial representation of the logical flow of information through a system. In this respect, they are similar to systems flowcharts. They have only four symbols, making them especially easy for users to understand. A set of DFDs can be constructed that begins at the overview level, and, through stepwise refinement, ends at a

very detailed level. Together with data dictionaries and process descriptions in structured English, the DFDs comprise the main tools of Yourdan's structured approach to system analysis and design.

Structured English

Structured English (SE) is pseudocode that is confined to the three basic control structures of sequence, selection, and repetition. Structured English uses cryptic, English-like phrases that are confined to a limited set of verbs such as WRITE, COMPUTE, ADD, and so forth as well as the data elements defined in the data dictionary.

HIPO Charts

HIPO stands for Hierarchy plus Input, Process, Output. There are two parts to this technique--both of them are graphic. The first part is a visual table of contents (VTOC) that sets up the modules in a hierarchy looking much like an organization chart. The second part is a three-section diagram that lists all input, all processes, and all output, and frequently is called an "IPO" chart. Upper level IPO charts are called overview diagrams; those on the bottom level are called detail diagrams.

Structure Charts

Structure charts are the same as a VTOC in the HIPO methodology. They lay out the hierarchy of the modules within a system including the span of control of modules. The only difference between the two tools is that the VTOC is always accompanied by a HIPO functional chart whereas the structure chart may stand alone.

Nassi-Schneiderman Diagrams

The Nassi-Schneiderman diagram (also called a structured flowchart) is a graphic logic aid tool that forces the analyst to work in a modular, top-down mode. There are three basic elements (process, decision, and iteration) contained within a box structure that represents the entire module.

Warnier-Orr Diagrams

Warnier-Orr diagrams resemble hierarchical charts laid on their sides so that the output or detail modules are on the right side and the control modules are on the left side. The symbols include braces that delineate each level of modules, "+"s to show alternation, and parentheses with numbers to show iteration.

Top-Down Analysis

Top-down analysis is an overall approach or methodology, not a tool. It occurs when the analyst begins at the overview or general level and makes stepwise refinements to end up at the lowest level of detail. This is an iterative process. The analysis, design, coding, testing, and installation steps occur at each level. The greatest advantage to this technique is that the difficult interface bugs are found very early in the development process rather than at the end when deadlines draw near. This is the opposite of the traditional development process that begins at the lowest level of detail and works up to the general level (bottom-up).

Structured Walkthroughs

Structured walkthroughs are a management

technique or methodology rather than a tool. The programmers and/or analysts meet on a routine basis and "walk through" their designs or codes with the other members of the team. The walkthroughs are meant to provide constructive criticism, consistency, and an opportunity to catch logic errors that typically are not detected until the testing phase. One beneficial side effect is that well-handled walk-throughs promote synergism and elevate team morale. Poorly handled walkthroughs actually can decrease morale primarily due to ego problems.

Prototyping

Prototyping is another overall approach that is concerned with developing a shell version of a system where most of the user interfaces such as screens and reports are developed very quickly in order to ensure that the user approves of the output. Many fourth-generation tools such as application generators and code libraries have facilitated prototyping. The problem with prototyping is that the user sees the shell and cannot understand why the end system takes so long. Users do not understand that the modeling and building of the data underlying the shell is the time-consuming and critical portion of system development.

End-User Computing

Several hardware and software advancements have occurred that allow end users to retrieve or generate information for themselves. The proliferation of microcomputers and the existence of local and wide-area networks have allowed physical access to computers. "User friendly" software such as database query languages and fourth-generation application packages such as spreadsheets and word processors have allowed users to create and retrieve information as they demand it. Information centers also have been created within organizations to aid users in this process.

EMPIRICAL STUDIES

In academia, most of these tools are taught on the premise that students will encounter them in the "real world." Several studies have been conducted to explore the use of tools in industry and to somehow relate the tools to enhanced productivity since that is their purpose. A study by Lientz and Swanson (1980) showed a significant correlation between budget levels and such tools as data dictionaries, test generators, HIPO charts, and chief programmer teams. As budget levels increase, the number of different tools utilized also increases.

A study by Guimaraes (1985) included a section on documentation tool usage, and concluded that system flowcharts, English narratives, and I/O layouts were the most frequently used tools from a maintenance programmer's standpoint. These three techniques are traditional and have been around a long time. The more structured documentation tools were utilized by a very few organizations.

Traditional analysis techniques focus on input/output and processing detail. Structured analysis focuses on structural aspects of systems (Colter, 1984). Each approach has communications strengths and weaknesses both between team members and between users and computing personnel. Ferguson (1983) suggests that regardless of which tools are utilized, the tools must

1. have adequate machine resources available

2. work together
3. address the real needs of developers
4. be supported by training and follow up

RESEARCH QUESTIONS

Although tool utilization has been studied and correlated with descriptive variables such as budget and length of existence of organizations, little attempt has been made to determine the effectiveness of these tools in regards to productivity enhancement. Has the "structured revolution" really hit industry? Which tools are being utilized in organizations? Which tools are considered to be effective? These questions should be addressed if:

1. End users are to intelligently select tools and methods appropriate to their needs.
2. Computer specialists are to gain expertise in those tools most valuable in achieving user satisfaction and career goals.

THE STUDY

Two hundred and fifty questionnaires were mailed to information resource directors of companies randomly selected from the Directory of Computer Facilities in Texas (1983). The response rate was 48.4%, very high for an industrial sample.

The variables measured by the questionnaire covered three main areas:

1. Descriptive or demographic information (tenure, number of personnel, budget, existence of an information center, and so forth.)
2. Performance information (user satisfaction, employee morale, deadline and cost overruns, postimplementation bugs)
3. Tool and methodology usage (eleven tools and methodologies measured on a 5-point Likert scale from "never utilized" to "frequently utilized"

FINDINGS

Since all of the companies are Texas based, using this sample may hamper generalization to all organizations. However, there is no reason why Texas organizations would be expected to be much different from those in the other states or in Canada.

Table 1 contains the condescripe findings of the study. Taking these findings and creating from them a "typical" organization using the arithmetic means of each demographic response yields a composite profile that includes the following facts:

* The "typical" organization obtained its first computer in 1971.
* The data processing staff includes 1.2 systems analysts, 4.9 programmers, 6.6 operations personnel, and .87 database administrators.
* The organization has an IBM mainframe or minicomputer and 20.3 microcomputers that are not networked.
* 2.8 months is required to complete the average project.

* Increasing proportions of deparmental time are incurred as the system life cycle proceeds--in analysis (15.5%), design (19.5%), implementation (27.8%), and maintenance (31.9%).

In terms of modal responses, it was learned that:

* Deadline and cost overruns are seldom experienced
* Post implementation bugs occur very frequently
* Morale of computer personnel is high.
* The company has not yet established an information center.
* The annual computing budget is below $100,000.

Table 2 lists the tools and methodologies described earlier along with the breakdown of responses. These usage patterns reveal that systems flowcharts and data flow diagrams are the only tools receiving consistent use (always" or "very frequently"). A second tier of usage includes structured English, decision tables, and structure charts. Tools receiving scant mention are HIPO, Nassi-Schneiderman, and Warnier-Orr. Of the methodologies, top-down analysis was often recognized as having consistent use, with structured walkthroughs and prototyping fairly close behind. All-in-all, the usage patterns, especially for the more publicized structured tools and methodologies, were disappointing. These usage patterns also are reflected in the ranking in Table 3.

Figure 1 shows the total number of tools used by organizations. Only 5% of the organizations utilized all 11 tools on a frequent basis. Almost 16% of the (15.7) organizations do not use any of the tools at all. The mean number of tools used by organizations was 3.

The ANOVA technique revealed a significant main effect between budget levels and the number of tools utilized ($F = 3.18$, $p = .016$). As the budget level increases, the number of tools also increases.

Tools and Productivity

In an effort to guage the impact of productivity tools on performance variables, correlation analysis was conducted between all of the performance variables and the individual tools, between the demographic variables and the individual tools, and between the performance variables and the demographic variables.

Top-down analysis (TDA) was found to correlate negatively with the number of postimplementation bugs in delivered systems. The number of bugs decreases as the utilization of TDA increases (Pearson Product Moment Correlation = -.2470, $p = .003$).

Utilization of systems flowcharts also was found to correlate with the number of postimplementation bugs, but the correlation was positive. The number of bugs increases with an increase in the utilization of systems flowcharts (PPMC = .2122, $p = .010$).

The level of morale of data processing employees also was found to correlate negatively with the utilization of Warnier-Orr diagrams (PPMC = 1.1779, $p = .025$). As the usage of Warnier-Orr diagrams increases, the morale of the employees decreases.

The number of microcomputers in an organization was found to correlate positively with several variables including the number of employees involv-

ed in analysis (.5383, p = .000), the number of employees involved in operations (.6841, p = .000), and the length of the typical development project (.3894, p = .000).

The correlations of the performance variables generally were high. This indicates that they are measures of the same underlying construct, which is that of system performance or success.

CONCLUSIONS

Tool utilization in industry is lower than expected. Only 5% of those organizations studied utilize all 11 tools on a frequent basis. Almost sixteen percent (15.7%) of the organizations do not use any of the tools. The ranking of the tools in terms of utilization identifies Data Flow Diagrams, Systems Flowcharts, and several of the structured methodologies as the most popular. Decision Tables and Nassi-Schneiderman diagrams are almost never used. Prototyping is utilized by 49% of the organizations to some degree. Prototyping has become more popular with the advent of fourth generation tools that lead to easy prototypes.

The research findings of Lientz and Swanson (1980) are confirmed with the significant effect of budget levels of organizations on the number of tools utilized. As the budget level increases, the number of utilized tools also increases. This makes sense, since many of the tools are expensive, require large amount of machine overhead, and require a sophisticated computer staff.

IBM mainframes or minicomputers were found in 39.5% of the organizations. This is consistent with the published market share information. The proliferation of microcomputers in these organizations is evident. The number of micros within a single organization ranged from 0 to 460. The mean was 20.3. Nineteen out of the 121 organizations only had microcomputers and had no mainframes or minis. Twenty-two of the organizations (18.2%) had no microcomputers.

An interesting finding centers around the amount of time spent in the various stages of system development. Research has shown that spending more time in the analysis and design stages leads to more successful and earlier completion of projects. Therefore, one question of interest to this study is how much time is actually spent in industry in the various phases--analysis, design, implementation, and maintenance. The mean times for each phase are analysis = 15.5%, design = 19.5%, implementation = 27.8%, and maintenance = 31.9%. This shows that many organizations in the sample are not devoting more time to analysis and design, but continue to spend the majority of time in implementation and maintenance.

The impact of productivity tools on performance yielded disappointing results. Very few of the performance variables were found to correlate favorably with the individual tools or the number of tools used by organizations. Top-down analysis did seem to contribute to fewer postimplementation bugs, but systems flowcharts seemed to produce more bugs. A surprising finding was that data processing employee morale seems to be lower in shops utilizing Warnier-Orr diagrams. Proponents of WOD are very enthusiastic about their usage and it would seem that shops using them would have higher morale. Of course, cause and effect cannot be determined by correlation analysis. So it is possible that some other variables are contributing to

low morale.

One reason that few significant relationships were found between the performance variables and the utilization of productivity tools is that the variables were measured by single subjective semantic differential scales using a mail survey. More reliable measures possibly could be obtained by looking at historical data relating to deadline and cost overruns, and postimplementation bugs. Employee morale can be more effectively measured by validated instruments such as the Job Description Survey (Hackmand and Oldham, 1971).

The findings concerning the utilization of the tools and the profiles of organizations are quite informative. Too many studies in MIS use only student populations, and seldom focus on industrial samples. Exploring the nature of computing in industry is necessary and meaningful, and helps to advance the knowledge base of MIS research.

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Table 1

Condescriptive Findings

Approximately when did your organization get its first computer?

Mean 1971
Range 1957-1983
Mode 1980 (12)

Approximately how many personnel do you have in the following categories?

Systems Analysis	Mean 1.2 People Range 0-30 Mode 1 (47)
Programming	Mean 4.9 People Range 0-100 Mode 1 (31)
Operations	Mean 6.6 People Range 0-190 Mode 1 (34)
Data Base	Mean 0.87 People Range 0-20 Mode 0

About how long does it take to complete the average computer project?

Mean 2.8 Months
Range 0-99 Months
Mode 1 Month

Approximately how many micros do you have?

Mean 20.3
Range 0-460
Mode 0 (22)

If you have micros, are any networked?

Yes 16 (13.2%)
No 98 (81%)
No Response 7

Approximately what percent of departmental time (person days) is devoted to the following system life cycle phases?

Analysis	Mean 15.5% Mode 20% Range 0-50%
Design	Mean 19.5% Mode 10% Range 0-60%
Implementation	Mean 27.8% Mode 20% Range 0-100%
Maintenance	Mean 31.9% Mode 0% Range 0-85%

Table 1 (cont.)

Has your company established an information center?

Yes	34(28.1%)
No	86 (71.1%)
No Response	1 (.8%)

Please indicate how frequently the following problems are typically encountered in implementing new systems:

Deadline Overruns	
Always	3 (2.5%)
Very Frequently	21 (17.4%)
Frequently	38 (31.4%)
Seldom	52 (43%)
Never	5 (4.1%)
No Response	2 (1.7%)
Cost Overruns	
Always	3 (2.5%)
Very Frequently	9 (7.4%)
Frequently	30 (24.8%)
Seldom	63 (52.1%)
Never	12 (9.9%)
No Response	4 (3.3%)
Postimplementation Bugs	
Always	6 (5%)
Very Frequently	82 (67.8%)
Frequently	29 (24%)
Seldom	4 (3.3%)

How would you rate the morale of the computer personnel?

Very High	16 (13.2%)
High	54 (44.6%)
Average	44 (36.4%)
Low	5 (4.1%)
Very Low	2 (1.7%)

What is the approximate annual budget for your computer operation?

Below $100,000	42 (34.7%)
$100,000-500,000	37 (30.6%)
$500,000-1,000,000	17 (14%)
over $1,000,000	23 (19%)

Table 2

Tool Usage

Please indicate how often your personnel use the following tools on a system development project.

Tool	Always	Very Frequently	Frequently	Seldom	Never
1. Systems Flow Charts	15(12%)	25(21%)	31(26%)	21(17%)	25(21%)
2. Decision Tables	1(.8%)	6(5%)	16(13%)	45(37%)	49(41%)
3. Data Flow Diagrams	11(9.1%)	18(14.9%)	35(29%)	30(25%)	25(21%)
4. Structured English	6(5%)	16(13%)	27(22%)	28(23%)	39(32%)
5. HIPO Charts	1(.8%)	2(1.7%)	2(1.7%)	35(29%)	75(62%)
6. Structure Charts	7(6%)	6(18%)	22(18%)	26(22%)	57(47%)
7. Nassi-Schneiderman Diagrams	3(3%)	1(.8%)	1(.8%)	18(15%)	93(77%)
8. Warnier-Orr Diagrams	0	0	4(3%)	19(16%)	91(75%)
Methodology					
9. Top-Down Analysis	10(8%)	29(24%)	20(16%)	23(19%)	36(30%)
10. Structured Walkthroughs	6(5%)	18(15%)	29(24%)	23(19%)	42(35%)
11. Prototyping	3(2.5%)	16(13%)	19(16%)	30(25%)	49(41%)

Table 3

Utilization of Tools and Methodologies

	% Of Organizations Utilizing
1. Data Flow Diagrams	79%
2. Systems Flowcharts	75%
3. Top-Down Analysis	70%
4. Structured Walkthroughs	65%
5. Structured English	61%
6. Prototyping	49%
7. Structure Charts	43%
8. Warnier-Orr Diagrams	25%
9. HIPO Charts	25%
10. Nassi-Schneiderman Diagrams	7%
11. Decision Tables	5%

Figure 1

Number of Tools Used by Organizations