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Characteristics of Application Software Maintenance

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Maintenance and enhancement of application software consume a major portion of the total life cycle cost of a system. Rough estimates of the total systems and programming resources consumed range as high as 75–80 percent in each category. However, the area has been given little attention in the literature. To analyze the problems in this area a questionnaire was developed and pretested. It was then submitted to 120 organizations. Respondents totaled 69. Responses were analyzed with the SPSS statistical package. The results of the analysis indicate that: (1) maintenance and enhancement do consume much of the total resources of systems and programming groups; (2) maintenance and enhancement tend to be viewed by management as at least somewhat more important than new application software development; (3) in maintenance and enhancement, problems of a management orientation tend to be more significant than those of a technical orientation; and (4) user demands for enhancements and extension constitute the most important management problem area.

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Introduction

The maintenance and enhancement of operational application software systems is frequently viewed as a phase of lesser importance than the design and development phases of the system life cycle. Maintenance and enhancement are generally defined as activities which keep systems operational and meet user needs (see, for example, Riggs [20]). A characterization of three types of maintenance activities has been presented by Swanson [22]. Briefly, these activities are: corrective maintenance (performed in response to the assessment of failures); adaptive maintenance (performed in anticipation of change within the data or processing environments); and perfective maintenance (performed to eliminate inefficiencies, enhance performance, or improve maintainability).

There have been a number of estimates of the amount of effort that goes into maintenance and enhancement. Riggs [20] cites a range of 40–60 percent of total systems and programming resources. Similar figures have been given in [5, 8, 11, 23]. An estimate as high as 75 percent of resources has been cited in [9] and [19]. A more conservative estimate of 40 percent has been given in [12, 13], and by Boehm [2]. A more recent estimate by Boehm [4] is 70 percent. Some of the specific problems in maintenance and enhancement have been the effect of hardware changes (Boehm [21]) and errors introduced with modifications (Kosy [14]).

Studies involving specific software systems include [21] and the excellent analysis of OS/360 by Belady and Lehman [1]. Some interesting ideas on maintenance have been stated by Brooks [6]. Other sources which take a management and implementation point of view include [7, 10, 16, and 17].

The purpose of this paper is to present some of the analysis results of an exploratory survey of organizations involved in maintenance and enhancement. Section 2 presents the data collection process employed and a profile of respondents. The statistical results appear in Section 3. Conclusions are given in Section 4.

2. Data Collection

This section summarizes the data collection process as well as the general profile of respondents. The questionnaire appears in [15].

The process of data collection began with the construction of an initial questionnaire and a field test of five organizations. Refinements were made and the form used for the survey finalized. Some 120 organizations were contacted by telephone and asked to participate. Managers of systems and programming departments were identified and requested to complete the questionnaire with staff assistance. Questionnaires were then mailed out to those expressing an interest in participation. Follow-up calls were made if no response was

received within two weeks. The total number of completed questionnaires returned was 69. This is a substantial percentage considering the length (35 pages) and depth of the questionnaire.

The questionnaire is composed of two parts. Part I deals with the systems and programming department and contains 12 questions in the following areas:

- industry category
- annual budget for software and hardware
- number of personnel in department (systems analysts and programmers as well as aggregate)
- division of tasks among staff in maintenance and new application work, and in analysis and programming
- management structure
- current percentage of effort in maintenance
- relative importance of maintenance compared to development
- reallocation of effort between maintenance and development, given hypothetical budget increases and decreases
- evaluation of adequacy of current levels of staffing.

The second part of the questionnaire deals with the application software undergoing maintenance and enhancement. Respondents were asked to select a system which has been operational for at least one year, represents a significant investment of time and effort, and is of fundamental importance to the organization. For this system they answered 38 questions on the following topics.

- name of system, function, and end users
- number of personnel in user groups*
- number of personnel in user groups actively involved in the system processing cycle*
- date system became operational
- number of programs maintained and number of source language statements broken down by language*
- distribution of source statements according to origination year*
- percentage of system dealing with online processing*
- total number of machine language statements*
- hardware/software environment of system
- use of distributed processing and/or database management systems
- number of files, average size of database*, percentage of database updated by time period*
- number and form of predefined user reports*
- productivity tools used in development
- time spent on maintenance*
- division of effort among types of maintenance activities*
- percentage of maintenance effort on online programs*, and in communication with user*
- number of people involved in maintenance of the system, the levels of their programming experience, when they began to work on the system, and task allocation in terms of analysis and programming
- formal procedures for maintenance request handling, number of requests received
- formal procedures for making changes to programs, and number of changes made
- formal procedure for trouble reporting
- existence of auditing, documentation, cost accounting procedures and chargeback methods
- problem areas in maintenance of the system.

In the above list, for the items marked with an asterisk (*), the respondents also answered the request: "Check the applicable statement: the above answer is: __ reasonably accurate, based on good data; __ a rough estimate, based on minimal data; or __ an estimate, not based on any data."

Table I. Annual budget distribution for equipment.

Budget ($1,000's)	Percentage
Under 250	14.5
250–500	15.9
500–1000	14.5
1000–2000	11.5
Over 2000	40.6

3. Analysis Results

This section is organized into the following categories: profile of respondents, tools and techniques employed, evaluation of maintenance, and interrelation of variables.

Profile of Respondents

Each respondent was asked to indicate the industry segment of their organization. A classification of the responses indicated: manufacturing, 27 (39.1 percent); and nonmanufacturing, 42 (60.9 percent). This distribution corresponds closely to that associated with a recent classification analysis of the organizational distribution of the journal of the Data Processing Management Association (37.7 percent manufacturing, 62.3 percent nonmanufacturing). However, some caution is in order in interpreting our selected sample as representative.

Several questions were asked relative to data processing equipment and expenditures. The response on equipment was similar to the division of the market and was IBM (73.9 percent), Burroughs (8.7 percent), Honeywell (5.8 percent), NCR (4.3 percent), Univac (4.3 percent), and others (2.8 percent).

The distribution of annual organizational budgets for hardware is given in Table I. It should be noted that these figures reflect total company expenditures, not simply departmental expenditures.

Several questions were asked on how development and maintenance effort would be redistributed if the systems and programming staff were increased or reduced by certain percentages. The results are summarized below (Table II) and indicate that most additional resources would go to new development. Also, as expected, most budget reductions would occur in new development.

At first glance, these results may appear to be inconsistent with the long-run historical trend of increasing budgets together with increasing proportions of effort devoted to maintenance. What is probably the case, however, is that the long-run rate of budget increases has failed to keep pace with the rising burden of systems to be maintained. Faced with this increased burden, management has been forced to cut back proportionally on its new development work. Thus, although management

Table II. Effect of budget difference.

Budget change	Distribution of change (percent)				
	New development		Maintenance and enhancement		
	Mean	Std. dev.	Mean	Std. dev.	Other
10 percent increase	6.6	3.4	3.1	3.3	.3
25 percent increase	15.6	6.7	8.3	6.2	1.1
10 percent decrease	7.3	3.3	2.4	3.3	.3
25 percent decrease	17.1	6.6	6.8	6.5	1.1

may plan to allocate a budget increase primarily to new development, the installation of new systems to be maintained tends to absorb such increases.

One major management issue involving maintenance centers on methods for charging back costs to the user. Of the sample, almost 60 percent (59.4 percent) do not charge back the use for operations or for maintenance and enhancement work. Of the respondents using a charge back method, 90 percent charge back both computer and personnel expenses.

Questions of budgeting levels lead to the issue of adequacy of staffing levels. Most felt that they were somewhat understaffed. The responses were:

substantially understaffed	8.7 percent
somewhat understaffed	60.9 percent
properly staffed	26.1 percent
somewhat overstaffed	4.3 percent

Several observations can be made on the organization of the respondents. When asked for a breakdown between analysts and programmers, most respondents have staff members assigned to both maintenance and enhancement of existing systems as well as development of new systems. Programming is treated as a separate activity by only 40.6 percent of respondents.

Of the respondents, 68.1 percent treated maintenance and enhancement of existing systems as a separate activity from the development of new systems. In terms of annual personnel hours allocated to maintenance and enhancement and new development, the results were:

maintenance and enhancement of existing systems	48.0 percent
new system development	46.1 percent
other activities	5.9 percent

This is among the lower estimates for maintenance effort cited in the literature. However, there were a significant number of cases (over 20 percent) that allocated 85 percent of their effort to maintenance and enhancement.

Within the maintenance and enhancement effort, the breakdown of activities in terms of the categories developed by Swanson [22] was:

Category	Activities	Relative frequency (percent)
Corrective	emergency fixes, routine debugging	17.4
Adaptive	accommodation of changes to data inputs and files and to hardware and system software	18.2
Perfective	user enhancements, improved documentation, recoding for computational efficiency	60.3
Other		4.1

In this setting, perfective maintenance is by far the biggest area of effort. Further, within this category, user enhancements account for about ⅔ of the total. This will be further supported later in Table VI, which indicates that user demands for enhancements and extensions are perceived by management to be the biggest problem.

Several questions were asked on accounting for user requests and system problems as well as auditing. It was found that 68.1 percent logged and documented maintenance and enhancement requests. A lower percentage (55.1) logged and documented operational problems with the application system. When asked whether a formal audit of the application system is made periodically, only 37.8 percent responded yes.

Tools and Techniques Employed

Respondents were asked to distribute the percentages of source code lines by language. As expected, the preponderance was in Cobol and Assembler. The distribution was:

Cobol	58.1 percent
Assembler	18.5 percent
RPG	10.2 percent
PL/I	3.1 percent
Fortran	2.6 percent
Algol	1.5 percent
Other	6.0 percent

A somewhat frequently made assertion in the literature is that productivity tools in design and programming are not yet widely employed in practice. This is substantially borne out in the percentages given in Table III. In Table III the most frequently used tool is decision tables (46.4 percent). Other tools in use by at least 30 percent of respondents included test data generators, online programming, and chief programmer teams. It is interesting to note that approximately one quarter of the sample indicated that they use structured programming. Responses other than those in Table III include modular programming, top-down testing, online simulator, copy library, and technical design review. It should be noted that the percentages from Table III reflect operational application systems; for systems currently being developed, the figures might be somewhat higher.

In related questions relatively few of the respondents indicated use either of database management systems (21.7 percent) or of distributed processing (4.3 percent).

Table III. Use of design and programming aids in development of systems maintained.

Tool	Frequency of use (percent)
Decision tables	46.4
Test data generator	36.2
Chief programmer team	30.4
Online programming	30.4
Database dictionary	26.1
Structured programming	24.6
Structured walk-thru	17.4
Automatic flowcharting	10.1
HIPO	7.2
ISDOS (automated design aid)	4.3

Evaluation of Maintenance

The respondents were asked to contrast the relative importance of maintenance with new system development within their organizations. A response summary appears in Table IV. It indicates that most view maintenance as more important than new development. More strikingly, few view new system development as more important.

Respondents were further asked to rank possible problem areas in maintenance. This is summarized in Table V. The table colums are arranged by problem area, statistics, and relative frequency. The statistics are based on the coding: 1—not a problem; 2—somewhat minor problem; 3—minor problem; 4—somewhat major problem; 5—major problem. Items marked with an asterisk indicated technical problem areas.

The only problem cited by the majority as more than minor is that of user demands for enhancements and extensions. Following this are two technical issues (quality of original program and quality of documentation) and one management issue (competing demands for personnel time). Frequently mentioned problems such as hardware change, turnover of maintenance personnel, and motivation of maintenance personnel showed up surprisingly low (means of 2.14, 2.46, and 2.03, respectively).

It is particularly interesting that maintenance programming productivity is not considered by management to be more than a somewhat minor problem. Given that quality of original programs and quality of documentation rank relatively high as problem areas, it would seem reasonable to expect that an increased investment in quality in the design phase would yield subsequent productivity increases in the maintenance phase. It is not clear whether management recognizes such a potential for productivity increases. In ranking the maintenance productivity problem relatively low, management may simply be saying that the programmers are productive, given what they have to work with.

In addition to the 24 areas that are mentioned in the questionnaire, respondents were encouraged to list other problem areas. Areas mentioned included quality of operations personnel, turnover in user organization, high learning curve due to large system, and retaining personnel at implementation time.

Table IV. Importance of maintenance and enhancement compared to new system development.

Maintenance and enhancement	Percentage
By far more important	33.3
Somewhat more important	21.7
Equal importance	34.8
Somewhat less important	5.8
By far less important	4.3

It is of interest to determine if management issues are more important than technical issues. This would serve as a guide in efforts to improve maintenance procedures and tools. Statistical tests indicate that management problems are more significant. To carry out the tests, the average problem rating was computed for technical and management areas for each respondent. The Mann Whitney-Wilcoxan and sign tests were selected to test the hypothesis that the distribution of the average response in each category was the same. These tests do not depend on actual scores but relative ratings. For the Mann Whitney-Wilcoxan test the hypothesis was rejected at the $\alpha = 0.10$ level. For the sign test it was rejected at the $\alpha = 0.01$ level. Both results indicated higher values for the management areas.

A second hypothesis is that the response to the problem of user demands for enhancements and extensions is significantly larger than the average for all problem areas. The same nonparametric tests were applied, and the hypothesis of the same distribution was rejected at the $\alpha = 0.10$ level. This indicates user demands for enhancements and extensions is more of a problem than other areas.

As was mentioned in Section 2, some of the questions were followed by questions on the quality of the data on which the answer was based. The results are summarized by average and relative frequency in Table VI. An asterisk indicates technical subjects. A question here is whether there is less data available for management-type questions than for technical-type questions. The results indicate respondents had firmer data for technical management types of questions. The statistical test was to test that the average responses to the management questions are based on data of a quality average equal to that of responses for technical questions. The nonparametric tests applied were the sign test and the Mann-Whitney Wilcoxan test. Both tests rejected the hypothesis at the $\alpha = 0.10$ level.

Similar tests (at $\alpha = 0.10$ level) indicated that respondents knew more about effort in maintenance and enhancement in general than specific tasks within maintenance and enhancement.

Interrelation of Variables

The previous subsections of this section were concerned with responses to individual questions. This subsection examines the responses for interrelationships between response items.

The analysis indicated that system characteristics,

Table V. Problem Areas.

Rank	Problem Area	Statistics			Relative frequency					
		Mean	Median	Std. dev.	Not prob.	Somewhat minor	Minor	Somewhat major	Major	No response
1	User demands for enhancements, extens.	3.42	3.72	1.25	7.2	20.3	11.6	36.2	18.8	5.8
2	Quality of syst. docum.*	2.99	3.03	1.33	17.4	15.9	26.1	20.3	14.5	5.8
3	Competing demands on maint. personnel time	2.95	3.00	1.39	17.4	24.6	8.7	29.0	13.0	7.2
4	Quality of original programs*	2.94	2.92	1.42	20.3	18.8	18.8	18.8	17.4	5.8
5	Meeting scheduled commitments	2.79	2.73	1.21	14.5	26.1	21.7	21.7	7.2	8.7
6	Lack of user understand. of syst.	2.66	2.53	1.19	17.4	29.0	21.7	20.3	5.8	5.8
7	Availability of main. program. personnel	2.66	2.53	1.27	20.3	26.1	21.7	17.4	8.7	5.8
8	Adequacy of syst. design spec.*	2.52	2.3	1.37	29.0	21.7	17.4	14.5	10.1	7.2
9	Turnover of mainten. personnel	2.46	2.13	1.46	36.2	17.4	13.0	15.9	11.6	5.8
10	Unrealistic user expectations	2.45	2.50	1.18	26.1	20.3	29.0	13.0	4.3	7.2
11	Processing time of system*	2.31	2.00	1.33	36.2	20.3	13.0	17.4	5.8	7.2
12	Forecast personnel requirements	2.30	2.03	1.28	33.3	23.2	13.0	17.4	4.3	8.7
13	Skills of maint. personnel*	2.20	1.94	1.24	34.8	26.1	15.9	10.1	5.8	7.2
14	Changes to hardware and software*	2.14	1.97	1.10	34.8	26.1	20.3	11.6	1.4	5.8
15	Budgetary pressures	2.09	1.82	1.18	37.7	27.5	11.6	13.0	2.9	7.2
16	Adherence to program. stds. in maint.*	2.08	1.94	1.04	34.8	26.1	23.2	7.2	1.4	7.2
17	Data integrity*	2.06	1.88	1.12	34.8	29.0	20.3	1.4	5.8	8.7
18	Motivation of maint. personnel	2.03	1.82	1.10	37.7	27.5	17.4	7.2	2.9	7.2
19	Applic. run failures*	2.00	1.90	.92	29.0	44.9	13.0	5.8	1.4	5.8
20	Maint. programming productivity*	2.00	1.87	.97	33.3	33.3	15.9	8.7	0	8.7
21	Hardware and software reliability*	1.91	1.76	.94	37.7	33.3	14.5	7.2	0	7.2
22	Storage requiremts.*	1.88	1.34	1.24	55.1	11.6	13.0	8.7	4.3	7.2
23	Mgmt. support of system	1.87	1.41	1.17	49.3	17.4	11.6	8.7	2.9	10.1
24	Lack of user interest in system	1.86	1.58	1.06	44.9	29.0	11.6	5.8	2.9	5.8

* Indicates problem of a technical nature.

Table VI. Quality of Data as Basis for Response.

Question topic	Answer based on			
	Reasonably accurate data	Minimal data	No data	Answer basis not indicated
Total mach. lang. statements*	13.0	21.7	26.1	39.1
Distrib. of source code over time*	46.4	29.0	18.8	5.8
No. of source lang. statements*	46.4	24.6	18.8	10.1
Percent personnel in input/output	49.3	26.1	14.5	10.1
Percent time period uptake database*	14.5	11.6	2.9	71.0
Size of database*	53.6	21.7	13.0	11.6
No. personnel in user organ.	53.6	29.0	11.6	5.8
Percent hrs. by activity in maintenance	49.3	37.7	8.7	4.3
Percent hrs. for user commun. in mainten.	46.4	36.2	13.0	4.3
Hrs. spent on maintenance	62.3	29.0	4.3	4.3
Form, freq. of user reports*	65.2	18.8	7.2	8.7
Number of user reports*	69.6	21.7	5.8	2.9
Percent statements used in online process*	81.2	7.2	10.1	1.4
Lang. used*	81.2	10.1	5.8	2.9
No. programs*	85.5	13.0	0	1.4
Percent hrs. for maintenance of online programs	82.6	11.6	2.9	2.9

* Indicates problem of a technical nature.

unit maintenance time, and other factors are not highly correlated. Unit maintenance time is measured as total personnel time in maintenance and enhancement divided by the total number of source statements maintained. The highest correlations obtained were between the number of programs in the system and the number of predefined user reports on a daily basis (correlation coefficient of 0.69) and between the total number of predefined user reports and unit maintenance time (correlation coefficient of 0.58). The factors contained in the correlation analysis included unit maintenance time, number of personnel in user units, percent of primary users engaged in input/output, size of database, number of files, number of programs, number of predefined user reports (total

and daily), date system became operational, and percentage of time spent in communication with user.

It has been suggested that, after a system becomes operational, the percent of effort in emergency repairs and routine debugging declines at first with time. It then increases as enhancement work changes the system and new errors are introduced. Some support for this was found in a regression analysis.

4. Conclusions

From the analysis of the survey data several tentative conclusions are suggested. It should be emphasized that these are based on the limited sample. The conclusions are:

- Maintenance and enhancement do consume much of the total resources of systems and programming groups.
- Maintenance and enhancement tend to be viewed by management as at least somewhat more important than new application software development.
- In maintenance and enhancement, problems of a management orientation tend to be more significant than those of a technical orientation.
- User demands for enhancements and extensions constitute the most important management problem area.

In general, more attention should be given to management problems associated with maintenance. In practice, maintenance work should be categorized to permit the gathering of more detailed management information. Project reporting systems should be detailed with respect to the type and tasks of maintenance and enhancement.

The handling of user requests for enhancements should be examined to determine means of better evaluating and satisfying requests.

Research into software design and program construction techniques should give fundamental consideration to issues of maintainability. In particular, consideration should be given to designing with future enhancements and extensions in mind.

Based upon the results reported here, the authors are currently pursuing a larger survey effort in cooperation with the Data Processing Management Association (DPMA).

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