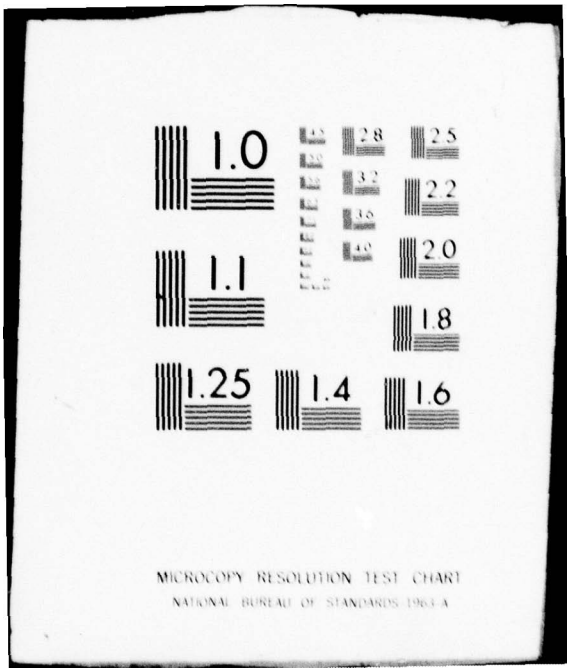
AD-A071 748 ALFRED P SLOAN SCHOOL OF MANAGEMENT CAMBRIDGE MASS C--ETC F/G 9/2
ARCHITECTURAL DESIGN OF A NEW M.I.T. BUDGETING SYSTEM: AN APPLI--ETC(U)
JUN 79 S L HUFF N00039-78-G-0160
UNCLASSIFIED CISR-P010-7906-11 NL

1 OF 2
AD A071748


1.0
1.1
1.25
1.4
1.6
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.8
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

(12)

LEVEL II

AD A071748

Center for Information Systems Research
Massachusetts Institute of Technology
Alfred P. Sloan School of Management
50 Memorial Drive
Cambridge, Massachusetts, 02139
617 253-1000

Contract Number N00039-78-G-0160 (Order 002)

Internal Report Number P010-7906-11

Deliverable Number 003

ARCHITECTURAL DESIGN OF A NEW M.I.T. BUDGETING SYSTEM: AN APPLICATION OF THE SYSTEMATIC DESIGN METHODOLOGY

Technical Report #11

S. L. Huff

June 1979

Principal Investigator:

Prof. S. E. Madnick

Prepared for:

Naval Electronic Systems Command
Washington, D. C.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: Technical Report #11	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): Architectural Design of a New M.I.T. Budgeting System: An Application of the Systematic Design Methodology.	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER: P010-7906-11
7. AUTHOR(s): S. L. Huff	8. CONTRACT OR GRANT NUMBER(s): N00039-78-G-0160 (Order 002)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Center for Information Systems Research, Sloan School of Management, M.I.T., Cambridge, Mass. 02139	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Electronic Systems Command	12. REPORT DATE: June 1979 13. NUMBER OF PAGES: 148 (151 p.)
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): CISR-P010-7906-11, CISR-TR-11	15. SECURITY CLASS. (of this report): Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Technical rept.,

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Software requirements analysis; functional requirements specifications; software architectual design; problem design structuring; application system preliminary design.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Recent research in software engineering and systems design has shown that many of the problems of cost, reliability, and modifiability of complex software systems arise because of fundamental design errors and oversights made during the early stages of systems design. While a number of other software researchers and practitioners have developed new design methodologies recently, none of them directly address such preliminary design issues. The Systematic Design Methodology, a new approach being developed by researchers

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

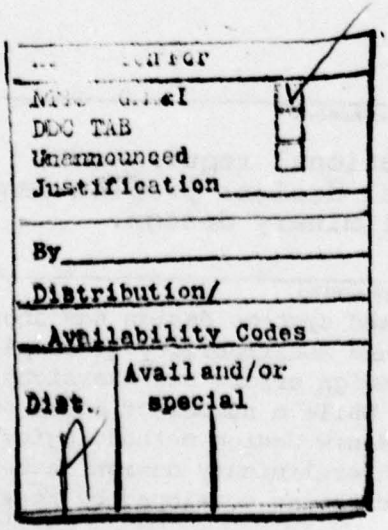
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

409 590

at the M.I.T. Sloan School of Management, consists of a set of concepts, analysis techniques, and tools to assist a software architect in synthesizing a design framework early in the design process. This report describes and analyzes the the results of an application of the Systematic Design Methodology to the architectural design of an "application" software system - a new Budgeting System currently under development by M.I.T.'s Office of Administrative Information Systems.

Following the introduction, Section 2 provides a description of the problem context. In Section 3, the various activities constituting the SDM analysis of the new Budgeting System are discussed, and certain important lessons learned there are reported. The SDM architecture for the new Budgeting System is presented and analyzed in Section 4.

Research implications and other conclusions are included in the final section. The reports appendices contain various documentation pertaining to the study.



PREFACE

The Center for Information Systems Research (CISR) is a research center of the M.I.T. Sloan School of Management. It consists of a group of management information systems specialists, including faculty members, full-time research staff, and student research assistants. The Center's general research thrust is to devise better means for designing, implementing, and maintaining application software, information systems, and decision support systems.

Within the context of the research effort sponsored by the Naval Electronics Systems Command under contract N00039-78-G-0160, CISR has proposed to conduct basic research on a systematic approach to the early phases of complex systems design. The main goal of this work is the development of a well-defined methodology to fill the gap between system requirements specification and detailed system design.

The research being performed under this contract builds directly upon results stemming from previous research carried out under contract N00039-77-C-0255. The main results of that work include a basic scheme for modelling a set of design problem requirements, techniques for decomposing the requirements set to form a design structure, and guidelines for using the methodology developed from experience gained in testing it on a specific, realistic design problem.

The present study aims to extend and enhance the previous work, primarily through efforts in the following areas:

1) additional testing of both the basic methodology, and proposed extensions, through application to other realistic design problems;

2) investigation of alternative methods for effectively coupling this methodology together with the preceding and following activities in the systems analysis and design cycle;

3) extensions of the earlier representational scheme to allow modelling of additional design-relevant information;

4) development of appropriate graph decomposition techniques and software support tools for testing out the proposed extensions.

This Document relates primarily to category (1) above. It reports the results of the application of the Systematic Design Methodology to the developement of a design architecture for a new Institute-wide Budgeting System for M.I.T. Various techniques and methods discussed in earlier reports of this series were used in the application study. This report discusses both the development of the system's architecture per se, as well as the ways in which the methodology was used by the designers, and the lessons learned in the study.

EXECUTIVE SUMMARY

Recent research in software engineering and systems design has shown that many of the problems of cost, reliability, and modifiability of complex software systems arise because of fundamental design errors and oversights made during the early stages of systems design. While a number of other software researchers and practitioners have developed new design methodologies recently, none of them directly address such preliminary design issues. The Systematic Design Methodology, a new approach being developed by researchers at the M.I.T. Sloan School of Management, consists of a set of concepts, analysis techniques, and tools to assist a software architect in synthesizing a design framework early in the design process. This report describes and analyzes the results of an application of the Systematic Design Methodology to the architectural design of an "application" software system - a new Budgeting System currently under development by M.I.T.'s Office of Administrative Information Systems.

Following the introduction, Section 2 provides a description of the problem context. In Section 3, the various activities constituting the SDM analysis of the new Budgeting System are discussed, and certain important lessons learned there are reported. The SDM architecture for the new Budgeting System is presented and analyzed in Section 4.

Research implications and other conclusions are included in the final section. The reports appendices contain various documentation pertaining to the study.

ACKNOWLEDGMENTS

The author would like to thank Lucky von Letkemann, Buck Shaw, and Anne Hartung for sharing a considerable amount of their time with him for the purposes of furthering this research. Their efforts, suggestions, and willingness to try something new are very much appreciated. Thanks are also due to Garrett Sheldon, Director of the Business Systems Development group for enthusiastically supporting this research.

TABLE OF CONTENTS

1. INTRODUCTION.

The 1970's will be remembered as the decade in which software considerations surpassed hardware considerations. Concerns about the cost, reliability, and ease of modification of complex computer-based systems are now largely focused on software, not hardware. Furthermore, it is becoming increasingly clear that these problems, although detected in late phases of the system development process, in fact very often arise because of basic mistakes made during the earlier, less structured phases (Horowitz 75, Thayer 75).

The change in priorities from hardware to software has led to the development of a collection of methods and ideas aimed at improving the software design and development process. While there are certainly some differences among these approaches, one important commonality shared by them all is that they do not attempt to address the early (preliminary, or architectural) phases of the system development process. For instance, Dr. G. Myers, primary developer of the Composite Design Methodology (one of the methods referred to above), points out:

> If the product being developed is a <u>system</u>, rather than a single program, there is another design process that must occur between the external design process and the use of composite design. This process, called system design, is the decomposition of the system into a set of individual

subsystems or individual programs. Although some of the ideas of composite design are appropriate here, and some people have claimed to have used composite design for this process, composite design does not appear to be directly applicable to system design. Therefore, when designing a system, as opposed to an individual program, the designer must first partition the system into distinct subsystems or programs. Then the methodology of composite design can be used to produce the structure of these individual pieces.

This preliminary partitioning task is not at all a trivial exercise. In fact, one of the reasons it has received so little research attention to date is simply that it has been viewed as analytically intractable - too deep and complex to be successfully structured and modelled.

The Systematic Design Methodology (SDM) is a new approach consisting of a set of concepts, analysis techniques, and tools to assist a software architect in synthesizing a design framework early in the design process. This framework should

1. Be based on a clearly stated set of requirement statements, expressed in the normal language of the system's users;

2. Convey the interdependencies, both tradeoffs and reinforcements, among system requirements as viewed by the designer;

3. Establish sets of strongly interdependent requirements, or design subproblems, that ought to be considered simultaneously for design purposes;

4. Suggest ways in which solutions to the alternative design subproblems ought to be coordinated so as to obtain an enduring global design.

The SDM is currently under development by software researchers at the M.I.T. Sloan School.

1.1 THE NEED FOR SDM EVALUATION.

The Systematic Design Methodology research to date has involved both methodology development and application studies. The applications addressed in earlier reports include designs for a database manager (Andreu 77(a)) and an operating system (Holden 78). In both cases, however, these studies were carried out by SDM researchers themselves - not by the "real" system designers. For this reason, they presented a somewhat biased result. For one thing, the individual performing the study was already very familiar with the methodology itself, its goals, and operational features. Thus there was little or no designer learning time involved (there was, however, learning time as regards the application being addressed). Furthermore, while these investigators did both report that using SDM seemed to provide both direct (an effective architecture) and ancillary (a better understanding of the system requirements) benefits, the credibility level of their assessments must be judged somewhat lower than would be those of a real system designer operating with a real design problem.

In order to determine how well SDM would perform in a real design context, and to learn how a practicing system architect would view and evaluate it, we undertook to locate an appropriate scenario within which to carry out such a study. Fourteen organizations were contacted by letter and then by telephone, and five indicated they (a) currently had

an appropriate design problem under consideration, and (b) would be willing to spare the manpower necessary to carry out such an evaluation. One of these organizations was M.I.T.'s own Business Systems Development (BSD) group. It was felt that BSD was the best choice for an initial outside application study for three different reasons. First, communication and transportation problems would clearly be nonexistant (all the other organizations were located in distant cities). Second, following an initial presentation of the concepts and objectives of the SDM, the BSD people concerned seemed genuinely interested and willing to expend some effort in a serious evaluation of the methodology. Finally, the system deemed most appropriate for the evaluation scenario was a fairly conventional, yet reasonably complex, data processing application system. As the earlier SDM applications had been concerned with systems software - a database management system and an operating system - this study promised to provide new insights as to SDM applicability to such application systems design.

This investigation, then, provides the first significant unbiased evaluation(1) of the usefulness and effectiveness of the methodology. Also, in return it provides the BSD system designers with an SDM-derived architecture upon which they may base the further detailed design and development of their target system.

---

(1) in the sense that the assessment data comes from real system designers, not the SDM researchers.

The remainder of this report is organized as follows. In the next section, background information on the target system, a new MIT computer-based budgeting system, is given. Section 3 contains a discussion of the process of applying the SDM to the Budget System architecture design, and includes certain observations made by the BSD designers, as well as lessons learned by the SDM researcher, in the course of working through the application. Section 4 describes the results of the graph decomposition calculations, and presents the system architecture that emerged from the SDM analysis. Implications of the suggested architecture are also discussed. Finally, the important lessons learned from this exercise are summarized in the Conclusions, Section 5. The appendices include various exhibits pertaining to the analysis and decomposition exercise, including original and final sets of requirement statements, and the interdependency assessments.

2. APPLICATION SYSTEM BACKGROUND - THE MIT BUDGETING SYSTEM.

In this section we provide brief background information on the specific application system being addressed in the study. The focus is a computer-based system to support the MIT budqetinq process. This system will be referred to as the Budqeting System. A clear distinction must be made between the present budgeting system, which is also partially computer based, and the new system being designed. Both the present system, and considerations for the new one, will be discussed below.

Much of the information presented below was gleaned from two sources: a Sloan School of Management Master's Thesis written by M. Gutierrez and U. Schirmer which provides a detailed description of the present MIT budgeting process, and supporting systems (Gutierrez and Schirmer 77); and, especially, a report written primarily by the chief designer of the new MIT Budgeting System, H. von Letkemann (von Letkemann 78).

2.1 CURRENT MIT BUDGETING ENVIRONMENT.

In this report the terms budget and budgeting are used in a broad context. They include financial planning and financial management, and therefore overlap with other ele-

ments, general planning at one end of the spectrum and specific accounting or reporting at the other. The terms include, but are not limited to, the existing Institute budget system, financial target setting procedures, forecasting of financial requirements, local departmental budgeting systems, and generation of various financial reports.

Budgeting functions at MIT take many forms. In this report these functions are divided according to the three levels of management primarily concerned with them. The titles listed for these three levels are examples and are not meant to be all inclusive.

1. Top Management - concerned with Institute-wide planning and management. This group includes the President, Chancellor, Provost, Treasurer, certain Vice Presidents and the supporting Finance and Budget Offices.

2. Senior Management - concerned with planning for, and management of, specific major components of the Institute. This group includes the Deans, Vice Presidents, Department Heads, and the Directors of Laboratories, Centers, and programs.

3. Administrative Management - concerned with carrying out the plans and supporting operations of senior management. They include Administrative Officers, and certain Administrative Assistants.

At MIT an overwhelming number of demands for funding compete for a finite amount of resources. The Institute has a fiscal 1979 operating budget of $336 million. Of this amount approximately $200 million is direct expense for sponsored research, $55 million for instruction and unsponsored research, and the balance for support services and auxiliary

activities. There are about 130 budgeting entities consisting of schools, academic departments, interdepartmental laboratories and centers, senior officers, support departments and special activities. The active accounts number about 10,000. Resources must be allocated among those programs in a manner consistent with the academic and societal goals of the Institute.

The Institute faces substantial fiscal pressures and constraints, both internal and external. It has considerable fixed expenses, including an extensive physical plant and a 60% tenured faculty. Recent shifts in enrolment patterns have strained the capacities of some departments and led to underutilization of others. Externally, the impact of inflation has been substantial. The cost of materials and services has gone up every year, and salaries and wages have been increased in an attempt to keep pace with the increased cost of living. Inflation has also aggravated a second key problem, the economic slowdown that the United States has experienced for the last several years. Although there are some indications of recovery, many sources of gifts and research sponsoring agencies, including government agencies, corporations, foundations and individuals, are still holding back because of their own economic problems. Additionally, problems such as the ever worsening energy crisis, and additional government regulations and requirements continue to burden the Institute's limited resources.

MIT's responses to these economic problems have taken several forms. Budget reductions have been necessitated in every area. For the most part these budget adjustments have been absorbed without detriment to the services provided. However, there is the general feeling that the easy cuts have been made and that future reductions will be more painful.

Major efforts are under way to develop new sources of recurring income and gifts to be used in operations. The Leadership Campaign, and the expansion of the Industrial Liaison Program, efforts by faculty to secure more sponsored research support, all are directed toward this goal. Various other Institute programs, including the new Facilities Management System to optimize building energy use, and increased undergraduate enrolment, have also been introduced to achieve further economies or additional income.

Some of the financial challenges which MIT faces will change with time and others will remain the same. New problems will arise and old ones will be solved, but it is clear that the Institute must use its resources wisely and efficiently if it is to continue to meet its goals of excellence in education and contribution to our society. With these goals in mind and the knowledge that resources are limited, it is essential for MIT to have a good system for budgeting and financial management.

2.2 THE EXISTING BUDGETING SYSTEM.

The budget system now used at MIT grew as a result of responses to specific requirements. As a need was recognized a new component of procedure came into existence. The system is soundly based on the MIT account structure and includes some analysis functions. These characteristics make it a valuable guide for any new system. However, it is still a loosely-connected mixture of manual procedures and computer operations. The system has not been developed sufficiently to take advantage of the available data already in the budget files and in those of the Accounts Reporting System (ARS). Other important data, particularly historical data, is not even in these files and must be developed manually from various sources. The functions of the existing budget system are hampered by the lack of an integrated base of consistent information. This has kept it from being the important management tool it could be. Some of the limitations of the existing procedures are discussed from the viewpoints of the various levels of management.

2.2.1 Top Management.

The reports used or issued by Top Management at MIT are predominantly manually produced. They are frequently prepared in response to changing requirements. Often the pertinent data does not exist in a computer-based file, or if it does the format or content may be inconsistent with other

files. Even periodic reports, such as the Treasurer's Report, the Operating Budget, the calculation of research overhead, the MIT Operating Plan (MITOP), and the Dynamic Model(2) are produced either entirely or partially by hand.

The manual preparation of a report does not necessarily detract from its value or content, but often this preparation requires extended periods of scarce managerial time. Production of reports either entirely or substantially by computer would use Institute resources more efficiently.

Cumbersome manual methods of handling information have a real impact on what information is used and what is done with it. For example, the Dynamic Model forecasts Institute financial scenarios several years into the future by projecting current data and assumed trends. Because of the time and difficulty involved in changing the assumptions and running additional iterations, only a limited number of combinations are reviewed. If the model could be changed more easily, more combinations of variables, and their relative impacts, could be assessed and it could be run more often. Then managers could spend their time more effectively in steering controllable elements and monitoring important external factors.

---

(2) For additional detail on these and other components of the current budgeting system, refer to (Gutierrez and Schirmer 77).

There is no system for looking ahead several years by collecting, evaluating and summarizing the planned activities and expense projections of the senior managers of the Institute on a regular basis. Even when setting budget targets with the Chancellor there often has been little attention paid to the years beyond the period being budgeted. Although many senior managers do their own longer range planning, these plans and projections are never brought together to show the aggregate of the estimates and their effect on where MIT will be three to five years hence.

Fund accounts are frequently managed in a less than optimal fashion. For instance, an unrestricted gift may be received and then designated for a specific use by the Institute. The fund is then accounted for according to that designation. In time that designation may begin to lose priority. With no easily accessible record to show that it was originally an unrestricted gift, there is no way to be sure that the gift is being used to the Institute's best benefit.

2.2.2 Senior Management.

As with top management, senior management must rely heavily on the current and previous year's figures when developing their future budget plans. Although certain items in their budgets will be adjusted by the Budget Office to reflect salary and tuition increases and other changes,

it is sometimes difficult to know what resources will be required for the coming year, particularly if any changes in activities are planned. The President, Chancellor and Provost give general guidance, but they depend heavily on the judgement of the deans regarding new subjects, trends in student demand, and research undertaken. The absence of uniform planning and budgeting presentations allows for a significant amount of subjective judgement to be exercised in the establishment of the budget targets.

In the cases where a request of the senior manager for a budget increase is accepted, it is likely that the request has been supported by a detailed and well structured projection explaining the requirment. Although no detailed justification nor any plan beyond the next fiscal year is normally required, it is often those managers who document their needs and provide the most meaningful presentations who get the most consideration for additional funding. However, the current budget system provides almost no effective support to those managers who are motivated to develop such thorough documentation.

2.2.3 Administrative Management.

Administrative management is the group closest to the day-to-day financial management of the Institute. As a group, it has the greatest need for current and detailed information about individual accounts. This function is

supported by the Institute with periodic reports such as those listed below.

The Accounts Reporting System (ARS) provides them with:

Detailed Transaction Report

Monthly Statement

Information Summary

Volume Report

Analysis of Expired and/or Overrun Accounts

The Budget Office provides them with:

Budget Proposal Forms

Budget Authorization (green sheet)

Budget versus Actual Analyses

The Payroll department produces:

Salary and Wage Expenses by Individual

Consolidated Salary Expense Analysis

The ARS reports contain essential accounting data, including information regarding monthly charges, fiscal year and cumulative figures, and authorized budgets. Commonly mentioned shortcomings of ARS reports are that the data is not timely and that the commitment figures are not always meaningful. These problems are inherent in the design of the current accounting and purchasing systems.

Budget vs. Actual reports produced by the Budget Office are the only real analyses that the Institute provides the administrative managers. These reports compare fiscal year-to-date expenditures with Budget Office projections

based on standard expenditure patterns. While the projections are generally sensible and realistic, not all administrators find them useful. Under the current system however, these reports are probably the best that could be produced on an Institute-wide basis.

In many instances, individual departments have developed their own tailored systems to monitor actual-versus-budgeted expenditures or provide other services deemed important by that department. The scope and sophistication of these "local" systems varies widely. However, their existence indicates the existence of a multitude of reporting and monitoring needs not now met by the current budgeting and accounting systems. They also represent a rich source of ideas for potential features of a new budgeting system.

2.3 GENERAL REQUIREMENTS FOR A NEW BUDGETING SYSTEM.

In this section, an overview of various user requirements for a new budgeting system is presented. These requirement issues are derived from many sources, including interviews with management personnel across the Institute, other interviews and questionnaire survey results from a study of the planning and budgeting practices of eleven other colleges and universities (Hudock 77), and analysis of the current MIT Budgeting System operational capabilities.

The new budget system will build on many strengths of the existing Budget system and the systems developed by several of the administrators. It will automate many of the manual procedures and extend the present system's capabilities by increasing the data available to both the Budget Office and the departmental users. Capabilities could be expanded by sharing the data bases of other systems and by making budget data available to users in other areas. Some additional input would allow improved support for a broad range of financial management applications and additional reporting capabilities. These features are discussed in this section in the context of the management level primarily involved.

2.3.1 Preliminary Technical Issues.

The present budgeting system is batch-oriented and heavily involves magnetic tapes for data storage. The new system would provide for considerable on-line function, as well as batch, and would rely much more on disk storage media. Tapes may still be used for disk backup, and possibly for transferring data between other older systems.

The new system will be developed and operated on one of the Institute's I.B.M. System/370 computers. Storage for the proposed database will require on the order of one full disk pack (3330-1 type). The system will be able to interface with different terminal types so as not to constrain

the system users. Any terminal which normally communicates with the 370/168 should be acceptable. A new printer, the IBM 3800, is desirable for the new system. It would allow more data to be shown on a report, could produce the reports in less time, and would print them on 8 1/2 by 11 inch paper. A sample copy of the 3800 output is included in Appendix A.

The new system will be designed to operate in conjunction with a database management system. The database management system (DBMS) will support storage of detailed information and allow simple access and updating through batch or interactive processing. The DBMS will support standard and non-standard reports and inquiries, and function independently of the programs and systems using it. It is planned that the database management system will interact with many systems, increasing its usefulness beyond just the budgetary function.

2.3.2 Support for Top Management.

These functions are categorized in three areas: special information requirements, standard reports, and planning.

Special information support for top management basically involves supporting the need for "one-time" reports or queries. Although it is not feasible to anticipate every request for such information, the Budget System must carry a

wide range of data that can be easily accessed, organized and presented as required. The details of this function are somewhat dependent on the capabilities of the database management system used. It is anticipated that the data would include at least the Chart of Accounts and detailed monthly budget and actual figures for each object code for each account. Certain data for past fiscal years would also be included. For fund accounts there would also be historical information that could facilitate their management. For example, fund data should include the donor's original designation for the gift and its related income as well as how it is currently being used, thereby making more effective fund management possible.

The new system would continue to produce most of the current standard reports, including (but not limited to):

The Printed Budget

Certain portions of the Treasurer's Report

Indirect Cost Recovery Percentage

MITOP

Dynamic Model

Periodic Summary of Operations

Modeling and analysis capabilities must be provided to explore historical data and to project observed trends and assumptions. This would probably require a new program to replace the Dynamic Model, which would automatically interrelate the various assumptions. This would facilitate re-

running the model so as to check out assumptions or do sensitivity analyses on individual factors. This modeling and analysis system could be developed in-house or a commercially available package might be used.

If MIT is to take full advantage of the new system's modeling and forcasting capability there must also be input concerning the plans made by top and senior management. The budget system would provide the support for collecting, storing and providing access to such data. The most important contribution to a forecasting system would be senior managers submitting their plans and projected expenses related to those plans. These should be for two specific periods; for example, a "short range" one year plan and a "long range" three year plan. The plans should be in a reasonably uniform format and should be correlated with proposed budget targets as well as the senior managers' area summaries in the Report of the President and Chancellor. The Budget and Fiscal Planning Office would then collect these plans and projections and enter them into a planning database to support modeling and forecasting.

2.3.3 Support for Senior Management.

The Budget System would provide senior managers with standard periodic reports, special reports and access to the database that would allow them to make their own inquiries and analyses. These reports would contain data extracted

from the Budget System database or any other file which is normally accessible.

Of the standard periodic reports currently produced by the Budget Office only the Budget Authorizations issued prior to the beginning of the fiscal year would remain the same. In the new system the subsequent budget authorizations and changes would be included in a Monthly Analysis report. The Monthly Analysis would also replace the Budget vs. Actual Report. This report would be a summary of the analyses produced for administrative management.

Special reports for senior management would be available on request. They would include variations of the Monthly Analysis report and other widely-used reports. It is anticipated that they would be reguested via a terminal and printed either at the terminal or on a high speed printer at the data center.

Customized reports could be obtained by use of an easy-to-use Report Writer language to access the database. Senior managers would be able to access their data, perform various kinds of calculations, and display the results in a variety of formats.

The Budget database would also be available for special inquiries or analyses originated by senior managers. There would be support for batch processing as well as a pre-programmed "menu" for terminals which would allow easy access to the database for the most common types of inquiries.

More complex analyses could be obtained by using an easily-learned database inquiry language.

Protection of data against unauthorized access would most probably be done by a system of passwords. Within a department there might be several levels of security depending upon the sensitivity of the data and the "need to know." Furthermore, even when data elements would be accessible to authorized users, most of them would be on a "read-only" basis. To maintain database integrity, only the data "owner" - such as ARS, Payroll, or Budget Office - would be allowed to add or change most data.

As for top management, there is a need for senior managers to submit their future plans and projected expenses. Not only will this aid top management in modeling and forecasting, but it will also assist senior managers in presenting a concise, meaningful and convincing proposal for their financial support.

2.3.4 Support for Administrative Management.

Just as the administrative managers have the most intimate and continuing contact with budget and accounting functions, they would experience the greatest impact from the new budget system. The system would make considerably more data available and would provide facilities to access it. It would also demand more of them, in that to effectively use the system they must provide, and revise as necessary,

month-by-month projections of expenditures and income for each account and object code. The system would make this as easy as possible to do. Each object code would have a standard or "default" projections formula which the administrators could either accept or replace with their own. Projection changes within an object code would be made directly by the Administrative Officer and reviewed by the Budget Office. Other changes to the budget data would be submitted to the Budget Office, which would be responsible, as it is today, for review prior to updating the database.

Program Budgeting can be an effective tool in relating plans or goals of the Institute and senior management to the financial resources available. It is a method by which budgets are established along program or activity lines. Although some administrative managers use Program Budgeting, others budget and monitor solely on a line-item basis. The new budget system should encourage the use of Program Budgeting. This budgetary method would be far more useful in monitoring expenditures than the traditional line-item budget. In addition, program budgeting would be a significant aid in estimating requirements and in preparing for the target-setting discussions between senior managers and the Chancellor.

The Budget System should provide manual and on-line options for the preparation and submission of budget proposals. Duplication of effort, and time to prepare proposals,

would be minimized by using the computer to do the calculations and make projections and modifications within the budget target amount.

The new system would supply all the periodic information currently contained in the Budget Authorizations (after the start of the fiscal year), Monthly Statements, Information Summaries, and the Budget vs. Actual reports. This would be done with a single Monthly Analysis report which would show current month, fiscal year to date, budget and other data in a format which would compare actual and planned account activity.

In addition to replacing these Institute reports, the system could eliminate the requirement for some of the departmentally-produced reports. If a department still wished to have its own special formats, they could do so by extracting their information from the database using the Report Writer feature.

The Budget System would produce optional reports on request. These would include standard reports for non-standard periods, such as contract year, or reports which would be widely, but not universally used.

The system would support the additional needs of administrators for inquiries into the database or for special analyses. Access to the data would be read-only, and, subject to data security restriction, would use the same facilities available to senior management.

2.3.5 Support for the Fiscal Planning and Budgeting Office.

The new budget system would cause some significant changes in the activities of the Fiscal Planning and Budget Office. In addition to most of its current responsibilities, there would be the establishment and maintenance of a database for the long range projections of the senior management. The dollar amounts and other volume figures should provide the Budget Office with the base for a good forecasting system.

Processing of budget proposals would be simplified by the use of computers and terminals, greatly reducing the routine manual functions. Proposals could be accepted either on paper or via department terminals. In either case, the computer would edit them for internal consistency and check or generate necessary totals. The computer would determine if the proposals were within the authorized target amounts and also check for open accounts without proposals. Any discrepancies would be followed up by the Budget Office.

The current procedures of written requests and approvals for nonrecurring equipment, carryforward amounts, sabbatical leaves and other special expenses would remain unchanged. The approval actions would enter the budget system as authorized budget changes.

The existing Fund Draft procedure would remain in effect, except the input log sheet would be replaced by a similar record entered via a terminal or batch input by the managing department and checked by the Budget Office.

The budget proposals accepted and approved by the Budget Office would continue to be adjusted for "dollar budgeting" via the computer, and Budget Authorizations ("green sheets") would be printed and distributed as at present. Once the fiscal year begins, any subsequent adjustments would appear on the new Monthly Analysis report produced from the Budget database. A note explaining the change would also be shown.

It is anticipated that the Budget database would have month-by-month figures for:

Proposed budget, next fiscal year
Authorized budget, this fiscal year
Actual expense, this fiscal year
Authorized budget, last fiscal year
Actual expense, last fiscal year

Summarized data would be included for prior years. The database would also carry, or be able to access, the data from the Chart of Accounts, account makeup and non-standard support, and additional data as required for fund and research accounts. Non-standard financial agreements between top and senior management, and other nonrecurring transactions, would be catalogued in a special Budget Office file. The database organization must allow the addition of data elements that are not currently required so that the database can grow and change with the needs of the Institute.

3. SDM ANALYSIS OF THE NEW BUDGETING SYSTEM.

In this section we describe briefly the steps that were taken in conducting the SDM analysis of the MIT Budgeting System, and the methodological lessons learned. The key documents developed or referenced during this activity are contained in appendices.

As mentioned earlier, the SDM researchers' "intervention" in the Budgeting System design activites commenced with a presentation on the nature and purpose of the methodology, attended by the MIT BSD staff. Following the presentation, it was agreed by the researchers and the BSD staff that the Budget System was probably the most appropriate system to use as an SDM test scenario. The main reason for this was that the system's development was at the right stage - i.e., most user requirements had been determined and documented, although detailed design activity had not yet commenced. Also, the system was perceived to be about the right size and scope for an effective SDM study: large enough to present considerable complexity to the designers, but not so large as to overwhelm the SDM researchers.

3.1 REQUIREMENTS PREPARATION.

The first step in the study was to prepare a set of SDM-oriented requirement statements for the new system. Following initial discussions with the Budget System designers, it was decided that the designers would prepare an initial requirements list, which would later be modified, if necessary. This initial list of statements was prepared by the two key Budget System designers, H. von Letkemann and R. Shaw, and is reproduced in entirety in Appendix B. These requirments statements were developed largely out of existing prose documentation of the needs of the various Budget System user groups, similar to the description given in Section 2.3

This initial set of requirement statements proved somewhat inappropriate for SDM use for various reasons. The most important difficulty concerned the manner in which many of the statements had been constructed by the designers. As may be seen in Appendix B, many statements consisted of a very general "leader" statement, followed by a series of sub-statements. For instance, original statement 19 was

19. Support Special reports for budget-related activities.
    a) Standard reports at non-standard times
    b) Standard reports for non-standard periods
        i) Contract period
        ii) Sponsor's fiscal year
    c) Standard data in non-standard formats

d) Report writer language for fully customized reports. This language must be easily learned and used.

Also, a number of the statements included reference to implementation mechanisms, something to be avoided at this stage in system design. As an example, original statement 18 read

18. On Personnel Action Form add a box to indicate whether person hired is a replacement or an addition.

It is clear that as stated, this requirement specifies a procedural technique rather than a function to be provided.

Finally, the various statements exhibited wide variations in their abstraction level. Statement 1, for instance, originally read

1. Automate as many manual procedures as feasible to save time and effort.

There is a rather substantial difference in abstraction level between statement 1 and statement 18 (above). In fact, statement 1 was later removed, as it was felt to be so all-encompassing as to be design-irrelevant.

Occasionally, the designers' original set of requirement statements included requirements for issues to be studied further, as opposed to the functions of the target system. For example, original statement 37 read

> 37. Determine the desirability and feasibility of encumbering salary and wage budgeted amounts.

Statements such as these were judged to be "study tasks," and were not included as system functional requirements in the final set of statements.

A two-stage approach was followed for re-writing the set of functional requirements to work them into a form more suitable for additional SDM analysis. In the first stage, the SDM researcher re-drafted all the statements following the general guidelines discussed in (Huff 78). The templates concept (see Huff 78) was followed in framing individual statements, and proved quite effective in helping to meet the guidelines.

In the second stage, the designers examined the re-drafted statements to make additions, corrections, and modifications. This took place over the course of two meetings, of about two hours each. One interesting phenomenon occurred at this point. In many instances, the designers possessed specific, often implementation-oriented, information that bore upon certain requirements. They felt that it was

important that such information be included within the requirement statements themselves. However, in many cases it was precisely this kind of detailed, implementation-oriented information that the requirements had been redrafted to avoid.

One of the underlying principles of SDM analysis is that requirement statements should specify functions only, not procedural issues. Including procedural information ("implementation issues") in the requirements tends to unnecessarily constrain later design options at the start, perhaps resulting in potentially superior alternatives never being considered. However, in this case the designers were effectively saying that various good procedural ideas had occurred to them, and they would "like to see them reflected in the requirement statements." Certain other factors played a role in the matter as well: wanting to include reference to a "pet idea" of particular users; wanting to include references to specific techniques or devices for which it was felt that higher authorities might require some "selling."

An effective solution to this problem was to add a Comment section to many of the requirement statements. This feature allowed the designers to include additional information, deemed not appropriate or relevant for the basic requirement statement, but which they desired to have formally stated along with the basic statements. Examples are contained in Appendix C.

The two meetings mentioned above led to a reasonable set of functional requirement statements for use in further SDM analysis. However, this was by no means the final version of the statements. In the meetings to follow, numerous additional modifications to both statement form and content were made. Certain new statements were added in light of improved understanding that occurred as a result of these discussions. Similarly, some other statements were deleted or merged together, and minor or major wording alterations were made to many. The final version of the Budgeting System Functional Requirement Statements is given in Appendix C.

Another mechanism found useful in the development of the requirement statements involved the use of the Waterloo Script text formatting system ("WSCRIPT") which runs on M.I.T.'s IBM System/370 computer. This powerful formatter allows the user to write command macros. One such macro was used to provide automatic numbering control on the requirement statements. Through this means, statements could be added, deleted, or their sequence altered, without requiring extensive and time-consuming statement renumbering.

3.2 INTERDEPENDENCY ANALYSIS.

Once the requirement statements had been expressed in a form appropriate to SDM, work began on determining the existence and strength of the various requirement interdependen-

cies. This work was carried out in a series of six joint meetings, each lasting about two hours.

A simple form was designed for carrying out the interdependency analysis, a copy of which is included here in Appendix D. The approach followed was straightforward. Beginning with requirement pair (1,2), each individual considered whether or not a significant implementation interdependency existed between the two requirements. This assessment was carried out by considering "conceptual models" of the implementation of each requirement in the pair, then determining in the context of these models whether or not there would arise any concordant or discordant interaction between them. These notions of mental implementation models, and concordant and discordant interdependencies have been described in depth in (Andreu 77(b)). The basic idea is as follows:

1. First, one thinks about how the first requirement would most likely be implemented. This generally requires thinking through some detailed design, procedural-type issues.

2. With that "mental model" in mind, the same thing is done as regards the second requirement.

3. Then the two mental models of implementation are jointly compared to determine whether

a) one scheme makes it easier to implement the other (condordance);

b) one scheme makes it more difficult to implement the other (discordance);

c) there is no appreciable overlap, or interaction, in the above sense, between the two.

The result of this comparison suggests the existence or non-existence of an interdependency between the requirements under consideration.

4. Finally, the strength of each interdependency was assessed. Strength ratings were chosen from a set of three alternatives:

S - strong

A - average

W - weak.

While interpolation and extrapolation of these categories are possible, these three alternatives were found to be satisfactory for this project. The interdependency strength assessment was made judgmentally, based on the perceived amount of "overlap," or interaction, between the mental models being contrasted.

In practice, the different individuals involved in the assessment activity nearly always agreed on a common strength value for a given interdependency. Intuitively, then, these assessments should be judged to be reasonably consistent between different designers.

Interdependency analysis proved to be somewhat more difficult for the designers than expected. The main reason for this seemed to be the difficulty in constantly keeping in mind precisely what interdependency assessment was supposed to be. Specifically, there was a noted tendency for the focus to shift from issues about how two particular requirements might be related at the implementation level, to whether or not they were logically related. An example of this phenomenon should make it clearer. Requirements 56 and 57 are, respectively

56. Budget proposals can be prepared manually.

57. Budget proposals can be prepared on-line.

Now, on first glance it might appear that since both requirements pertain to budget proposal preparation, they must have an interdependency, probably a strong one. This would be an instance of what was termed "logical relationship," above. In practice, this kind of logical relationship is easier to identify than is the implementation-level interdependency, consequently they often "jumped out" at the designers during the interdependency analysis activity, tending to further obscure the search for true implementation interdependencies. The only solution to this problem was for the SDM researcher to continually ask the designers

whether a given interdependency they had determined to exist was in fact a result of implementation overlap, or something else. If the answer was "something else" (e.g., in the above example, the source of the initial interdependency assessment was "both requirements concern budget proposal preparation") then we had to think more carefully about the requirements and our mental models of their implementation within the target system. In the above example, this rethinking did in fact lead to an implementation interdependency, judged to be weak in importance. The underlying argument concerned a key implementation model, the concept of a suspense or holding file for budget proposals, that was seen as leading to a concordant interdependency between the two requirements.

3.3 SOME LESSONS LEARNED.

The interdependency analysis activity, as mentioned above, consumed approximately eleven hours of meeting time. This is a not inconsiderable load. However, in this case at least, the meetings were judged to be profitable exercises in a sense independent of any potential benefits that may emerge from the SDM-produced architecture per se. Specifically, some important issues regarding the Budget System were raised, discussed, and cleared up or at least better understood as a result of the careful, repeated study being given to each requirement. This effect is raised and dis-

cussed, and modelled as an important SDM benefit in (Huff 79b).

The most general side benefit gained from the SDM analysis exercise concerned a heightened awareness and understanding of all the "pieces" of the new Budget System, and now they fit together. The designers indicated that working through the SDM activities, especially the interdependency analysis step, served both an integrating and differentiating function. Developing implementation-free requirement statements tended to force them to "stand back," to abstract from many of the specific implementation-oriented details with which they were generally concerned, thus helping them to develop a better grasp of the "big picture." An example of this concerns original requirement

5c) Provide checks to ensure that each person is not budgeted more than 100% E.F.T.

Discussion of this requirement led to the broader recognition that what was really desired was a general set of editing and checking capabilities, not limited to this one particular aspect. Hence the more general requirement,

58. Budgeted proposals will be automatically checked and edited to the extent possible.

emerged. Nonetheless, the problem with EFT (effective full-time) budgeting of certain staff occasionally exceeding 100% was felt to be an important instance of the general requirement, so was included in the final set of requirements as a comment.

Another class of lessons learned concerns new ideas that occurred to the designers as a result of working through the SDM analysis. A good example of this was related by the chief designer during one of the meetings. It concerned his observation of the parallels between the research proposal tracking and budget proposal tracking tasks. In the past these activities were viewed and treated separately. However, through having to think carefully about the relationships among the requirements in the course of the interdependency analysis, he had come to recognise many procedural commonalities between the two general activities. This, he pointed out, suggested new, potentially better ways of performing the former task based on ideas that had been developed for performing the latter. At the present time the procedures for performing the two tasks are quite different. Essentially, the need to develop a mental implementation model for the research proposal tracking requirement led the designer to consider a similar, better understood model for the budget proposal tracking requirement, which in turn led to the idea of implementing both requirements in a common fashion. This may be thought of as

a kind of inverted interdependency analysis: rather than deriving the interdependency from the conceptual implementation models, one implemented model was derived from the second model and the perceived potential interdependency. The normal and inverted patterns of interdependency analysis are illustrated in Figure 3.1(a) and (b).

A third category of benefit reported by the designers was that working with the SDM concepts gave them some useful new ways of thinking about system design in general (not restricted to this specific system). The most frequently cited case concerned the central SDM concept of separating functional issues in the requirement statements, and implementation issues in the interdependency assessments. The designers reported that they found this a most useful way of organizing their thoughts in addressing system design problems, and in fact found themselves using the concepts when discussing design issues with other parties. They reported conversations with the Business Systems Development manager (their boss) in which the SDM conceptual framework was used to help clarify certain design issues being discussed.

Another category of "lesson" that ought to be mentioned concerns the importance of what we will call "political" issues in the system preliminary design process. As with practically any activity that results in impacts on the working needs and relationships of the members of the organization in which it operates, system design activities are

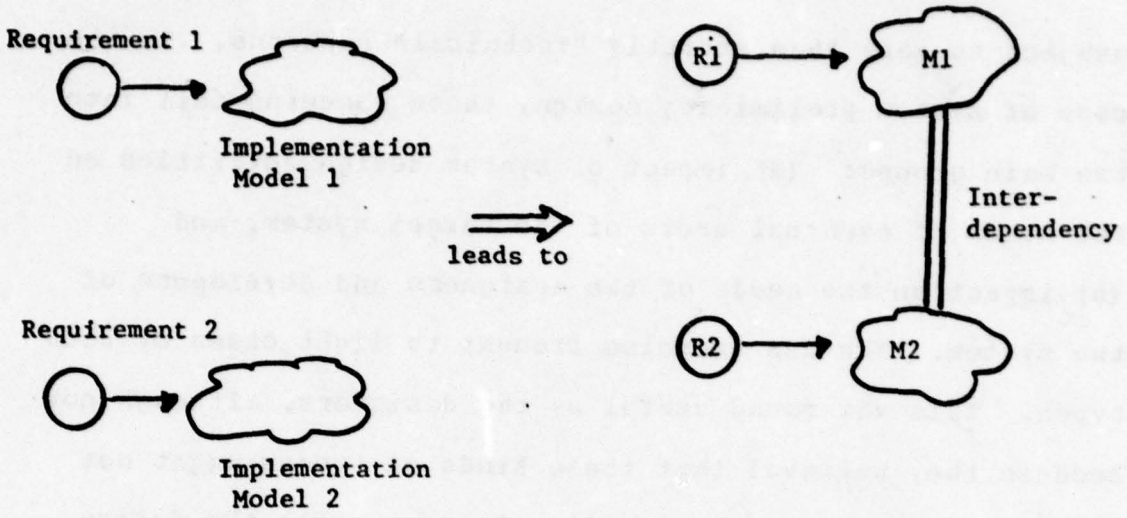


Figure 3.1(a)

Normal pattern for Interdependency Assessment

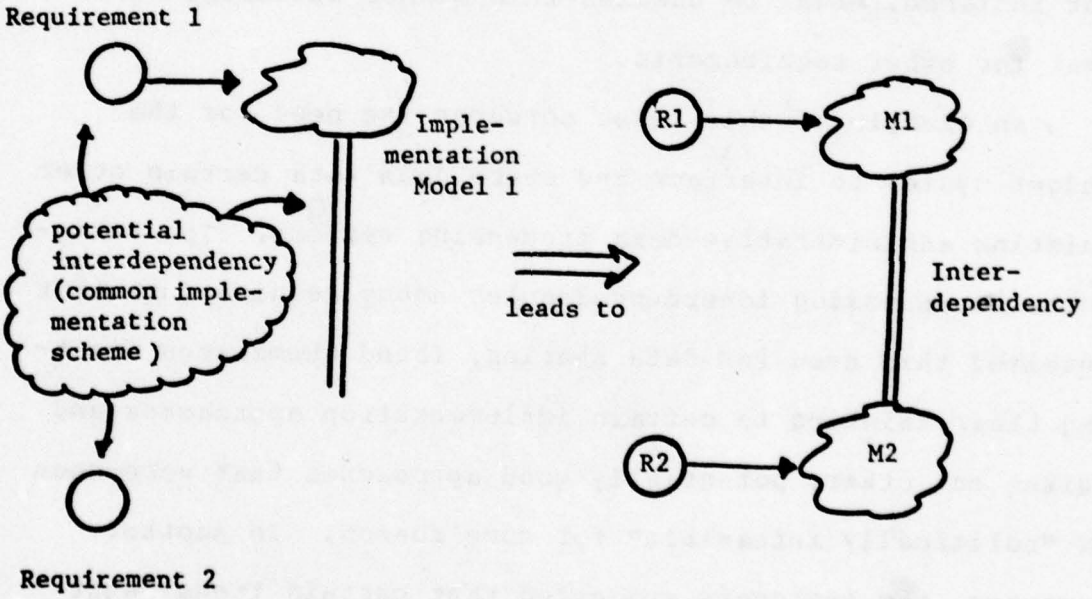


Figure 3.1(b)

Inverted pattern for Interdependency Assessment

subject to more than strictly "technical" concerns. In the case of system preliminary design, these concerns fall into two main groups: (a) impact of system design activities on the needs of eventual users of the target system, and (b) impact on the needs of the designers and developers of the system. The SDM exercise brought to light cases of both types. This was found useful by the designers, although not because they believed that these kinds of issues ought not enter the design process at all. In most cases the designers were not really in a position to make such a judgment. Rather, it was seen to be beneficial simply to recognise the nature of the reasoning underlying such considerations. Design decisions involving "politically-based" requirements, for instance, might be handled in a manner different than that for other requirements.

An example of this issue concerns the need for the Budget System to interface and share data with certain other existing administrative data processing systems. The designers, in assessing interdependencies among requirements that involved this need for data sharing, found themselves limiting their thinking to certain implementation approaches and ruling out other, potentially good approaches that were seen as "politically infeasible" for some reason. In another instance, the designers suggested that certain items ought to be included (generally as comments) in the SDM requirement statements on the grounds that some other individual or

organizational entity "would want to see it there." There were also some instances of comment items stemming from the designers' desires to give expression to particular techniques or approaches they felt to be especially important. As a hypothetical example, a designer might be convinced (perhaps quite correctly) that a particular device would be necessary to properly meet one or more user requirements. Therefore, even though the choice of device could be argued to be an "implementation approach" to meeting the requirements, the designer might choose to include a reference to the particular device as a comment on the requirement statement, so as to help develop a mental association between the device and the requirement in the minds of the users reading the requirement statements later on.

Andreu expressed concern over the time required to execute the SDM interdependency analysis on requirements sets of nontrivial size (Andreu 78). He countered this concern, however, with the observation that the interdependency matrix is quite sparse, hence the problem is not as serious as it might at first appear. This turned out to be accurate in the present case as well. For the Budgeting System, 77 requirements were determined, and 289 interdependency assessments made over a course of about 12 hours. This represents approximately four interdependencies per requirement, and approximately 2.4 minutes per assessment. Note however, that the total potential number of interdependen-

cies is 77x76/2 = 2926. Using the total figure, the assessment rate turned out to be 15 seconds per interdependency assessment. The fact that about 90% of the requirement pairs are of the "easy" assessment type, and hence require very little study time, makes the entire interdependency assessment activity feasible.

In carrying out his DBMS application study, Andreu performed all the interdependency assessment himself - i.e., he played the role of a single DBMS designer. He later pointed out (Andreu 78, page 232) the fact that he felt a group approach to the assessment activity might work out well, in that individual designers need reinforcement of their thinking process from other designers to insure them that they are not "way off base." This in fact did seem to be the case with the Budgeting System assessment exercise. Having three people thinking about the interdependencies definitely resulted in a clearer and more consistent set of interdependency, and in the propagation of ideas, modification and improvements to the requirements, etc. that would not all have been generated by any single individual. An effective balance - between target system-relevant knowledge possessed by the designers, and SDM-oriented concepts better understood by the SDM researcher - was in evidence. On numerous occasions, the SDM researcher suggested possible interdependencies that were discounted by the designers as a result of their better grasp of the needs of the target system. In

contrast, the SDM researcher was effective in maintaining the correct focus during the requirement statement development and interdependency assessment activities, as discussed earlier. The materialization of this symbiosis suggests that a group approach to interdependency assessment is probably the most fruitful one.

3.4 SUMMARY.

This exercise has indicated clearly that there are immediate design benefits to be had from the SDM requirements preparation and interdependency analysis activities. The common source of these benefits lies partially in the simple fact of having to think carefully, and repeatedly, in a structured way, about what each requirement really means, about how each might be implemented, and about how alternative implementation schemes interact. In the next section we analyze the architecture for the new Budgeting System that emerges from this analysis.

4. AN ARCHITECTURE FOR MIT'S NEW BUDGETING SYSTEM.

Once the interdependency analysis has been completed, the interdependency statements can be entered into the computer for use in the decomposition analysis. The Budgeting System interdependency statements are of the form:

node1 node2 weight description

The weight values are entered as 'W', 'A', or 'S', as discussed earlier. The "description" is a brief text commentary used to document the rationale underlying the designers' assessment of the existence of that particular interdependency. A complete listing of the Budgeting System interdependencies is given in Appendix E.

It should be noted that the capability of entering, storing, and retrieving interdependency descriptive information was judged by Andreu to be an important feature not present in his initial version of the SDM analysis package. While the techniques that have been developed for this purpose in the current effort have been found useful, there are some further improvements that could be made, and are discussed in the final section.

4.1 DECOMPOSITION ANALYSIS RESULTS.

The Budgeting System interdependencies define its requirements graph. The interdependencies data file (Appendix E) was converted, using the analysis package, to another data file (containing no text information) that could then be used as input to the MASTER decomposition routines. These routines were described and documented in (Huff 79a).

The facilities of the analysis package were then used to develop decompositions of the requirements graph, to evaluate them using the objective function M, to modify and manipulate the decompositions in various ways, and to save and print out the results so obtained.

Each of the five decomposition techniques (four clustering techniques, and the interchange algorithm) were applied to the Budgeting System requirements graph. The outcomes are shown in Table 4.1. Of the four clustering methods, HIER3 produced the best overall decomposition, with an objective function value of M = 0.67. The objective function values for HIER1, HIER2, and HIER4(3) were, respectively, 0.05, 0.27, and 0.27.

The interchange algorithm was also applied to the requirements graph, and produced a decomposition with M = 0.85. This decomposition, then, was judged to be the best in terms of identifying high-strength, low-coupling subgraphs (as measured by M). This best decomposition of

---

(3) These algorithms are discussed in detail in (Huff 79a).

Algorithm	Objective Function Value for Best Located Decomposition
HIER1	0.05
HIER2	0.27
HIER3	0.67
HIER4	0.27
INTERCHANGE	0.85

Table 4.1

Comparison of results of five decomposition algorithms on the Budgeting System requirements graph

the requirements graph produced by the interchange method is illustrated in Figure 4.1. Appendix F contains a listing of the abbreviated Budgeting System requirements (no Comment sections included there, for brevity) organized according to subgraph. Finally, Appendix G contains a listing of the inter-requirement links between each identified pair of subgraphs.

The task that remains, then, is to study the decomposition - both the requirements subsets, and the sets of interdependencies between requirement subsets - so as to formulate an interpretation of the graph decomposition as a system architecture. At the same time we seek to identify anomalies, courterintuitive results, etc., that might indicate earlier errors in assessments, requirements formulation, etc. Alternatively, anomalous results might turn out, on closer inspection, to be correct after all, but simply unforseen. Such issues will be examined in greater detail in the next section.

4.2 ANALYSIS OF DESIGN SUBPROBLEMS.

A total of eleven design subproblems were identified in the best decomposition of the requirements graph. Three of these subproblems are "middle-sized," containing 15, 19, and 13 requirements; the remainder are somewhat smaller, ranging in size from two to seven requirements each.

Subgraph	Requirements
1	7,28,38,56,57-62,65,66,68,71,76
2	18-26,29,31-34,36,39-42
3	16,43-52,64,74
4	15,77
5	9,10,13
6	53-55,67,69,70
7	11,12,14
8	5,6,27,35
9	8,63,75
10	1-4,17,30,37
11	72,73

Figure 4.1

Best located decomposition produced by the interchange method on the Budgeting System requirements graph.

Figure 4.2 shows the relationships between the eleven design subproblems and the 21 inter-subproblem linkages. This figure will be expanded with additional descriptive information following our discussion of the individual subproblems and linkages in this and the next section.

Subproblem 1 - Preparation of Budget Proposals.

This subproblem centers on the preparation of budget proposals. One of the intended features of the new Budgeting System is a much more streamlined, easier-to-use set of proposal preparation facilities, including on-line preparation, automatic checking and cross-checking of entered data for consistency and reasonableness of values, on-line examination by the Budget Office, and on-line modification by the budget preparers (administrative officers, department heads, etc.). Most of the requirements in this subproblem hinge directly on these related activities.

Requirements 7, 28, 38, 62, and 68 all are related to the maintenance of various kinds of data directly relevant to proposal preparation. The fact that these data sources are identified together is useful for later detailed design of the Budgeting System database - e.g., when deciding on segment structure, record layouts, etc., it is most useful to have a clear idea of what data is most likely to be used jointly or in closely related activities.

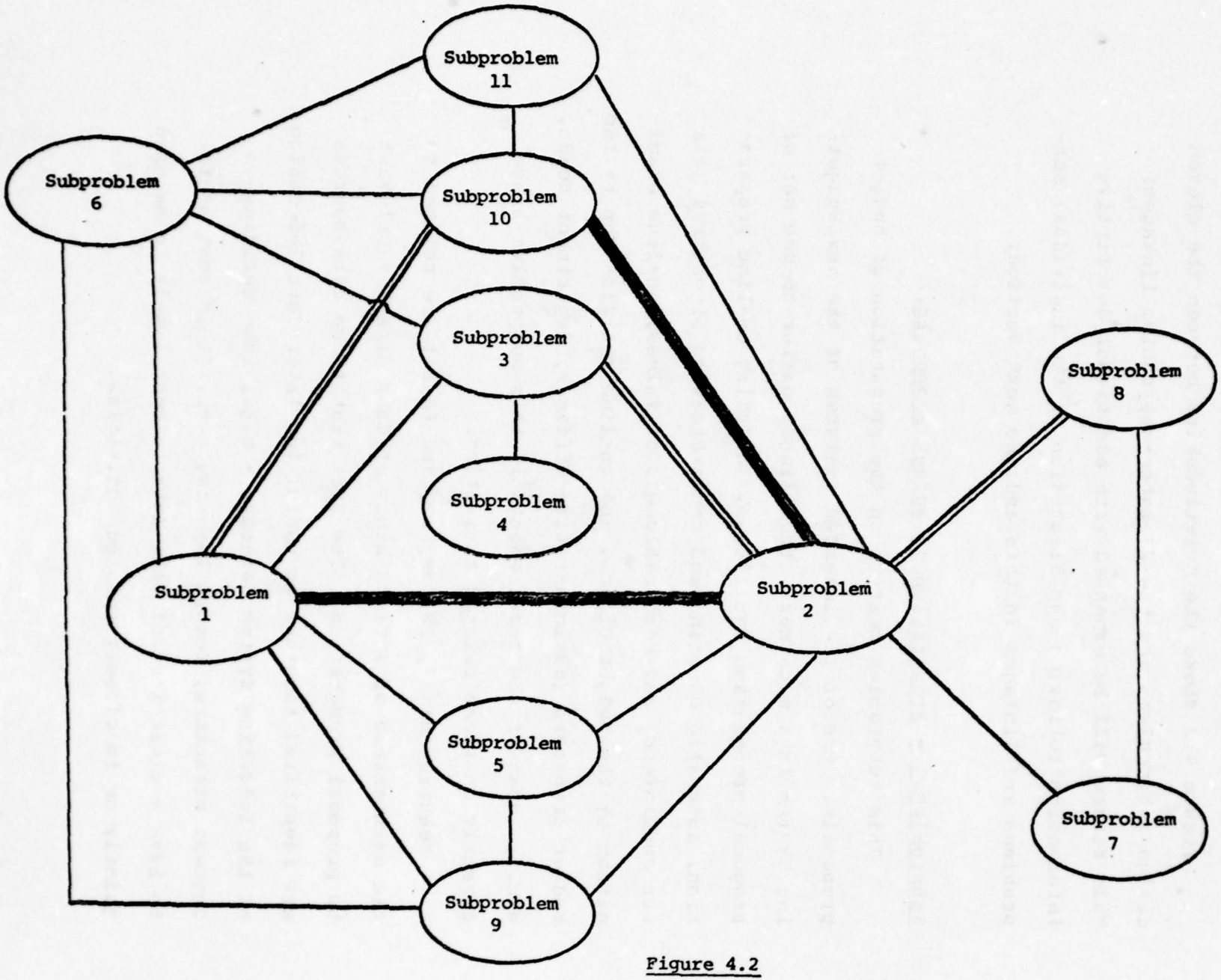


Figure 4.2

Relationships among the eleven design subgraphs

Requirements 56 and 57 pertain to the proposal preparation process itself. Requirements 58, 59, 60, and 61 all pertain to the issues surrounding the checking, editing, and revision of budget proposals or changes to pending proposals. Requirement 71, regarding fund draft checking, is closely tied to various other requirements within this subproblem, including those involved with special financial arrangements (7,68), and those requirements with similar processing steps (59,60,61,62).

There are two seeming anomalies, in the presence of requirements 65, 66, and 76 in this subproblem. A deeper examination, however, reinforces the correctness of this assignment. Requirements 65 and 66 involve handling of research proposals by the Budgeting System. Research proposals may not appear at first glance to have much in common with budget proposals. However, as discussed in Section 3.3 earlier, one of the useful discoveries made by the chief designer in the course of the SDM interdependency analysis was the existence of strong potential <u>implementation</u> parallels between the handling of research and budget proposal preparation.(4) These parallels manifest themselves in interdependencies that eventually result in the research proposal preparation requirements being grouped together, for design consideration purposes, with the budget proposal

---

(4) specifically, the use of a common suspense file approach pending final acceptance of the proposals.

preparation requirements.

The existence of requirement 76 in Subproblem 1 similarly makes good sense upon closer examination. The Institute's overhead recovery rate is, in fact, a key item of information in budget proposal preparation. The rate is adjusted as a function of the Institute's financial situation each year. The intention in the new Budgeting System is to estimate the rate for the coming fiscal year on the basis of information available in the budget proposals (hence requirement 76) and make this estimate available to the budget officers for their proposal preparation activities. Thus the manner in which recovery rate calculations are made is closely tied in with proposal preparation, so should be considered together for design purposes.

Subproblem 2 - Operations Reporting.

The second subproblem is the largest in terms of the number of requirements included: 19 requirements. Its central focus might be termed "operations reporting." Basically, this subproblem addresses monitoring of actual income and expense information against the operating budget - i.e., the control side of the budgetary process. Since this is perhaps the largest and most important function to be provided by the new Budgeting System, it is most appropriate that it should also turn out to be the focus of the largest design subproblem.

Certain of the requirements in this subgroup directly address the operational analysis and reporting capabilities of the new system, including requirements 18, 19, 29, 31, 33, and 39. Many of the remaining requirements ended up in this group because of strong data interrelationships between them and the ones cited above. This includes requirements 20 through 26. These requirements specify that certain databases will be maintained by the Budgeting System, databases intimately linked to the provision of the monitoring and reporting functions to be provided.

It is interesting to note that these requirements end up together in the requirements decomposition because of their data-oriented interrelationships, as opposed to their processing interrelationships. One of the recent "discoveries" in software engineering research concerns the frequently underestimated importance of the role of data structures and data handling in system design. Earlier work usually assumed program control flow to be the pre-eminent concern, data organization to be of secondary importance; more recent work has tended to elevate the relative importance of data organization (Jackson 75). The evidence that emerges from the present study is that SDM is inherently quite compatable with this more balanced view of the importance of both processing and data interrelationships in determining good system structure.

Finally, a few other requirements fall into this subproblem because they specify reporting needs that would be met primarily using data common to other requirements of the same subproblem. Included here are requirements 34, 36, 40, 41, and 42. All five of these statements refer to potential reporting requirements of various types that all would most likely involve budget and actual operational data common to other requirements in this subproblem.

In summary, while Subproblem 2 is a fairly large subproblem, careful study indicates that the 19 requirements do "hang together" for design purposes, largely as a result of their common data implications.

Subproblem 3 - Database Access for Nonstandard Report Generation.

The third subproblem contains 13 requirements. The focus of this subproblem is database access for purposes other than standard report generation. This includes requirements for users' ad-hoc access (requirements 44 and 45), users' access via the report writing facility (requirements 43 and 46), and access to the Budgeting System's databases via other systems (requirement 16). This subproblem also includes certain database security requirements that pertain to user access, namely, requirement 47 through 52. These requirements all relate to data ownership and data element controls that are closely related to data ownership.

Since these security issues manifest themselves, in implementation terms, primarily at the point of data access, it makes very good sense that they be grouped together with other data access requirements.

The presence of requirement 74 in this subproblem also makes good sense: formal training issues would undoubtedly be heavily concerned with data access, as this would be the main interest of most users. An interesting side point regarding this requirement is that, at first glance, it may not appear to be a design-relevant issue at all. This question was in fact debated among the system designers and the SDM researcher, with (eventually) the opposite conclusion. The main argument ran as follows. There is no requirement stating that the system (specifically, access to data) be "easy for users to use." Such a requirement would be too general, at too high an abstraction level, to be appropriate for SDM analysis. In contrast, requirement 74, specifying the need for formal user training, is more specific, at an abstraction level comparable with the other requirements, and at the same time achieves most of the same results. In thinking about how one might "implement" a requirement such as 74, one is led to imagine what a trainer would have to say to explain various aspects of system functioning thought to be of interest to different user groups. Thinking in this way leads the system designers to adjust their conceptual models of implementation for the associated requirements, with an eye to the need for formal training.

Finally, requirement 64 (support for current budgeting techniques) also ended up in Subproblem 3. The case for this requirement being in this subproblem is not obvious initially. However, a review of the "audit trail" of interdependency assessments indicates that requirement 64 was found to be interdependent with only two other requirements: weakly with 32 (Subproblem 2), and with average strength with requirement 74 (Subproblem 3). Its ending up in the present subproblem is therefore justifiable on purely "mechanical" grounds. The rationale for its interdependency with 74 concerns user training. Formal training on the one hand, and support for all budgeting methods on the other, are seen to be discordant requirements. Through this line of reasoning one can envision second-order relationships between 64 and many of the other requirements in Subproblem 3, bearing on the fact that a multitude of budgeting approaches would probably make the implementation of user access to data, and control of data, more difficult to achieve. Clearly, users may require access to different data combinations under, say, line item budgeting than they would under program budgeting. However, the fact remains that requirement 64 is only tangentially concerned with the main focus of Subproblem 3, but as it is no "closer" to any other subproblem, it ended up there.

Subproblem 4 - Physical Report Handling.

This subproblem only contains two requirements, and is therefore rather easy to interpret. Its focus is physical report handling. One requirement (15) concerns the report medium, specifying that reports will be physically easy to handle. In implementation terms, this may be viewed as arguing against the production of reports on standard 11x14 inch computer paper, and suggests the use of 8 1/2 x 11 inch paper for reports. In fact, this requirement is an example of a situation discussed earlier: the designers' original requirement statement (see Appendix H, requirement 7) actually specified the way in which this requirement could be achieved, i.e., contained within it its own implementation approach. In the spirit of SDM analysis, the requirement was re-written so as to be functional in form, and implementation-free. However, as the designers did not want to lose sight of their implementation concept (and indeed wanted other readers of the requirement statements to be aware of it also) they decided to keep it, in the form of a comment on requirement 15 (Appendix C).

The other requirement in this subproblem, 77, simply says that the new Budgeting system should be designed so as to minimize unnecessary delay in report production and distribution. A discordant interdependency between requirements 15 and 17 occurs because one way of meeting 77 would be to employ a number of RJE terminals or remote printers at

user sites; but this would likely result in reports being printed on large forms, thereby counteracting requirement 15.

Subproblem 5 - Use of EFT to Define Personnel Levels.

Subproblem 5 contains three requirements, and is straightforward to interpret. The central focus for this subproblem is the use of EFT ("effective full-time") units for dealing with personnel data. The idea is that many administrative officers (AO's) find it easier to think in terms of EFT units for personnel budgets than in dollar terms, hence requirement 9 specifies that EFT may in fact be employed to develop personnel budgets. However, as budgets are necessarily framed eventually in dollar terms, there must be a mechanism within the Budgeting System for converting between EFT and dollars. This is not as simple a task as it may at first appear; a number of detailed issues have to be considered, and the conversion algorithms may be rather complex.

Finally, requirement 13 specifies the need for flexibility in manpower reporting (as opposed to budgeting). In practice it is easier to report some types of manpower in man-months, other types in, say, man-hours, etc. Clearly, allowing such reporting flexibility complicates still further the dollars-EFT conversion issue, hence this requirement's presence here.

Subproblem 6 - Maintenance of Database Integrity, Control.

This subproblem includes six requirements, and has as a central focus the maintenance of database integrity and control. Requirements 53, 54, 55, and 67 all relate directly to this issue in various ways. It should be noted that these requirements impact system design primarily in the choice of a commercial DBMS to be used as the heart of the new system, as there is no intent in the minds of the designers to develop their own underlying data management software.

Requirements 69 and 70 pertain to computerized funds drafts being performed, either on-line or via batch transactions. Once again, these requirements might appear to be rather distant from the preceding four. Closer examination dispels this notion, and confirms again the correctness of the partitioning. Funds drafting, and the checking and verification thereof, is perhaps the most sensitive data-handling aspect of the new system, as it deals directly with the movement and control of real, spendable credits.(5) Therefore the requirements to allow electronic funds drafting in the new system are especially closely related to the integrity concerns, notably the audit trail requirement (67). In implementing the integrity requirements, very close attention will also have to be paid simultaneously to the funds drafting issue.

---

(5) most of the system's databases will consist of budget data, or else real expense (credit) data.

The separation of requirements 69 and 70 from other requirements dealing with funds (see Subproblem 10) is another good example of the issue discussed on page 34, concerning the need to carefully differentiate between requirements that are logically related (e.g., all requirements dealing with funds), and those that are related in implementation terms.

Subproblem 7 - Organization of Budgeting/Accounting Objects.

This subproblem includes three requirements. The subproblem's focus is the organization of the budgeting/accounting "objects." This term has an unambiguous meaning to the budgeting and administrative staff of the Institute. "Objects" represent one way of organizing the elements of income and expenditure of the Institute; for instance, "secretarial salaries" might be an expenditure object, while "federal grants" might be a revenue object. In the present budgeting system, there is a fixed set of objects, and codes for each object, with which all concerned must work.(6)

The new system, as these requirements indicate, is to have greater flexibility in terms of object definition. Specifically, it will be possible to define multiple hierarchies of objects. Also, departments will be able to define

---

(6)at least as far as the central budgeting office is concerned, although many departments also run their own parallel systems that better meet their specific needs.

their own personal objects within the central system.

The three requirements of this subproblem are clearly related quite closely for implementation purposes. In particular, it may be noted that the requirements for multiple object hierarchies (11 and 12) probably rule out the possibility of using a hierarchically-oriented commercial DBMS such as IBM's Information Management System (IBM 74) for the system's database manager.

Subproblem 8 - Development and Management of Planning Data.

This subproblem contains four requirements, and has as its focus the development and management of Institute intermediate-range planning data. Planning data differs from budget data in a number of ways. First, its development is neither homogeneous nor universal across the Institute. Some departments develop much more, and more highly detailed, planning data than do others; some plan up to two years ahead, others up to three years, still others five years out. Also, the nature of the data differs from budget data, often being more in the form of descriptions of underlying goals, directions, etc., for a given department, rather than hard numbers at a relatively fine level of detail.

During their analysis of the present planning/budgeting practice, the Budget System designers found a need for some level of automated assistance to the planning function of

various administrative staff. Since this function is fairly closely related to the budgeting function, to include some planning assistance capabilities in the new system seemed appropriate. Requirements 5 and 6 address the planning data issue directly. Requirement 35 concerns data requirements for the "Dynamic Model" - M.I.T.'s financial forecasting model. Since many of the model's data requirements are in the nature of planning data, it is appropriate that this requirement fall in the current subproblem. Specifically, the determination of the type of planning data to be obtained from the Institute managers ought to be influenced directly by the data needs of the model.

The inclusion of requirement 27 in this subproblem is another instance of a surprisingly intelligent outcome of the SDM decomposition. While logically related (in the sense discussed on page 34) to requirements 21 through 26, this requirement differs on one very important respect: historical actual data is the key database referenced by managers and administrators in drawing up their intermediate-range plans. None of the other requirements 21-26 have this property. The implementation of planning assistance facilities in the new Budgeting System must take into consideration both what planning data will be captured, and what data will be required by managers in developing their plans. Requirements 5 and 6 correspond to the former concern, requirement 27 to the latter.

Subproblem 9 - Employee Benefit Rate Calculations.

This subproblem, with three requirements, concerns employee benefit rate calculations. In the present budgeting system, management of employee benefits may present some complexities, especially when a) amounts budgeted for personnel expenses are used for non-personnel expense items, and vice versa; b) dollar budgeting blanket adjustments are made, such as changing the rate of benefits as a percent of salary; and c) when non-standard employee benefit rates must be applied due to contract provisions, retroactive changes, mismatchs of fiscal years, etc.

A typical example of these problematic issues might involve a department's budget that is approved given a certain staffing profile. That profile may then be altered through substitution of certain staff members for others (e.g., increasing the number of individuals assigned to a particular research project). This kind of change may require a compensating change in employee benefit amounts being charged to that department. Such a change is, at present, frequently "lost in the shuffle." Subproblem 9 addresses the need for an effective mechanism for controlling the employee benefit issue within the Current and Future budgets.

Since employee benefit amounts are a percentage of personnel salaries and wages, it makes good sense that requirement 8 be included in this subproblem. Similarly, require-

ment 75 is concerned with handling non-standard employee benefits (e.g., benefits for a part-time faculty member), which are subject to very similar needs for control as are standard benefits.

Subproblem 10 - Organization and Management of Fund Accounts.

There are seven requirements in Subproblem 10. The focus of this subproblem is the organization and management of fund accounts. At the heart of this design subproblem is requirement 30, "...facilitate the effective use of funds accounts." The other requirements in this subproblem (with one exception, to be explained shortly) all partially derive from requirement 30. Requirements 1, 2, and 3 all specify alternative ways in which fund data may be organized (and hence retrieved during queries, etc.). Requirement 4 addresses the need to supply adequate descriptive information for each fund account within the database itself. Requirement 37 pertains to reporting standard fund information. Finally, requirement 17 specifies the need for access to data in the databases of other Institute DP systems. The system designers saw this as closely associated with effective fund management, largely because much of the information that would be needed in order for requirement 30 to be properly implemented resides in the Gift System.(7) A direct

(7) This is the system that is used to manage gifts, bequests, etc.

link to the latter system would be superior to duplicating and separately maintaining the necessary databases.

Subproblem 11 - Database Expandability.

The final subproblem contains two requirements, and its focus is database expandability. Specifically, requirements 72 and 73 state that, unlike the present budgeting system, the new system will allow new data elements to be defined within objects or accounts, in order to provide additional flexibility and usefulness for the system's users. For instance, one department may wish to summarize a certain set of account balances in a unique way. The new system would allow a special data item to be defined to hold the appropriate summary data, and also to tie the new item logically to the lower-level items it summarizes, so that when changes are made to the lower-level items the summary item will also be updated.(8) This requirement ties into the concept of logical data independence that has come to prominence along with the use of database management systems (Martin 77).

* * * * *

This concludes the analysis and interpretation of the eleven identified system design subproblems. The subproblems and their interpretations are summarized in Table 4.2. In the next section we analyze the interrelationships (sets of interdependencies) between the various subproblems. The

---

(8)either actually or virtually - see (Folinus, et. al. 76).

Subproblem	Summary Description
1	Preparation of budget proposals
2	Operations reporting
3	Database access for purposes other than standard report generation
4	Physical report handling
5	Use of EFT to define personnel levels
6	Maintenance of database integrity, control
7	Organization of budgeting/accounting objects
8	Development and management of planning data
9	Employee benefit rate calculations
10	Organization and management of fund accounts
11	Database expandability

Table 4.2

Subproblem Summary Descriptions.

combined interpretation of subproblem and interrelationship analyses constitutes the architecture interpretation for the new Budqeting System. The final section contains concluding comments pertaining to global aspects of this architecture.

4.3 ANALYSIS OF SUBPROBLEM INTERRELATIONSHIPS.

There is a total of 21 links interconnecting the 11 design subproblems in the new Budgeting System architecture. Some statistics regarding these links are shown in Table 4.3 below. It is shown there that the average number of interdependencies per subproblem link is 4.5; however, there are only five links consisting of more than five interdependencies. Since both number of interdependencies as well as interdependency weights are important determinants of link strength, Table 4.3 also shows total weight for each link. This is just the sum of the weights on all the interdependencies making up each link. From this table it may be seen that the distribution of link total weights is as shown in Figure 4.3 below. From the figure, it is clear that the design partitioning has two rather strongly interconnected subproblems ((1,2), and (2,10)), three subproblem linkages of medium strength ((1,10), (2,3), and (2,8)), while the remaining subproblem linkages have a total weight of less than 2.0, so are relatively weakly connected. In the diagram of Figure 4.2 earlier, the strongest linkages are shown shaded, the medium-weight ones are drawn as double lines, while the remainder are shown as single lines.

ID #	First Subproblem	Second Subproblem	Number of Linking Interdc-pendencies	Total Weight	Average Weight
1	1	2	20	7.6	0.38
2	1	3	5	1.9	0.38
3	1	5	4	1.1	0.28
4	1	6	3	1.2	0.40
5	1	9	4	1.4	0.35
6	1	10	10	3.8	0.38
7	2	3	7	3.2	0.46
8	2	5	2	1.0	0.50
9	2	7	2	1.3	0.65
10	2	8	10	3.8	0.38
11	2	9	2	1.0	0.50
12	2	10	16	6.8	0.43
13	2	11	5	1.9	0.38
14	3	4	1	0.5	0.50
15	3	6	2	0.7	0.35
16	5	9	2	1.3	0.65
17	6	9	3	0.9	0.30
18	6	10	3	0.9	0.30
19	6	11	1	0.5	0.50
20	7	8	1	0.5	0.50
21	10	11	1	0.8	0.80

Table 4.3

Statistics for the Inter-subproblem Linkages

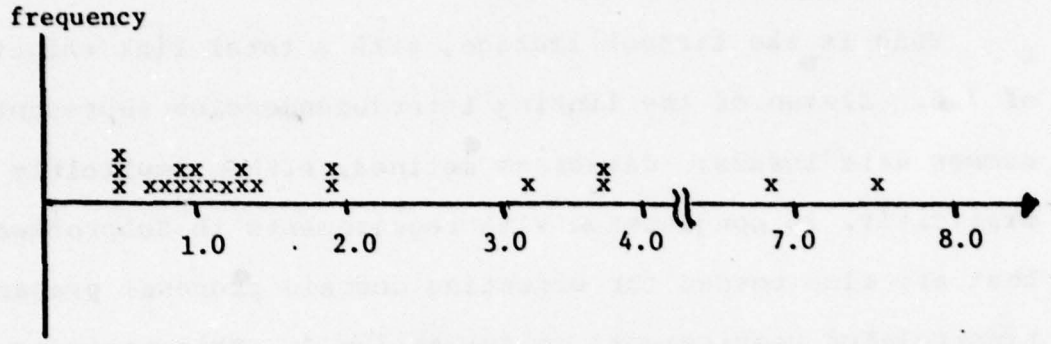


Figure 4.3

Distribution of Link Total Weights.

It is worth recalling at this point that the underlying motivation for this entire SDM exercise is to formulate a system architecture which exhibits high module strength and low coupling. The objective function M, of course, is a formal attempt to quantify that concept. Informally and judgmentally, a system decomposition with only two relatively strongly interconnected subproblem pairs, three pairs with medium interconnection strength, and fifteen with relatively weak interconnection strength should probably be judged as a fairly good one from this point of view.

We now examine each subproblem linkage, and describe an interpretation of the nature of, and the reasoning behind, each.

Linkage 1 (Subproblems 1 and 2).

This is the largest linkage, with a total link weight of 7.6. Eleven of the linking interdependencies represent common data issues: databases defined, either implicitly or explicitly, in conjunction with requirements in Subproblem 2 that are also needed for effecting certain proposal preparation-related requirements in Subproblem 1. This includes in particular Chart of Accounts data, and Current and Future Budget databases.

The remaining linking interdependencies represent concordant relationships that arise because of common processing techniques. In one case, the automatic proration feature may be used to good effect in proposal preparation as well as operations monitoring activities; in the other case, potential methods of operational monitoring facilitate certain aspects of monitoring proposal preparation.

Linkage 2 (Subproblems 1 and 3).

This linkage has a total weight of 1.9, and includes five interdependencies. Two of the interdependencies represent the need for training users to use the system for proposal preparation. The other three represent the use of the menu-oriented query facility for proposal and fund draft review and checking.

Linkage 3 (Subproblems 1 and 5).

This linkage consists of four interdependencies, with a total weight of 1.1. The common focus for all four concerns the ability of users to prepare and/or monitor the personnel component of budget proposals in the most convenient units (typically, EFT or dollars).

Linkage 4 (Subproblems 1 and 6).

This linkage includes three interdependencies, with total weight 1.2. The process of preparing budget proposals (Subproblem 1) requires administrators to access various kinds of data that will, in the future, be available via the new system. The focus of this linkage concerns the implementation issues surrounding protecting the security and integrity (Subproblem 6) of the data that will be accessed for proposal preparation purposes.

Linkage 5 (Subproblems 1 and 9).

This linkage includes four interdependencies, and has a total weight of 1.4. These interdependencies all pertain to the role of employee benefit calculations in the proposal preparation process.

Linkage 6 (Subproblems 1 and 10).

This linkage contains 10 interdependencies, and has a total weight of 3.8. Subproblem 1 addresses budget proposal preparation generally, and the requirements within Subproblem 1 that connect to Subproblem 10 are concerned specifically with the role that funds play in proposal preparation. Subproblem 10 focuses on the orgainzation and use of fund accounts. Good information is the key to better management of Institute funds (gifts, bequests, etc.). At the present time fund monies are frequently not used to their greatest benefit, because individuals who make expenditure decisions haven't been informed of, and have no easy way of discovering, the existence of certain funds whose designation meets their needs. The intention in the new Budgeting System is to make fund purpose information readily available to users, and to otherwise orient the reporting and control of fund data so as to make more effective use of fund monies. This would conserve general monies to more fully meet the needs to which funds do not apply.

Linkage 7 (Subproblems 2 and 3).

This linkage contains seven interdependencies, with total weight of 3.2. All seven interdependencies have a fairly strong common focus: they all represent techniques to allow users to access data in a manner other than via standard reports (special reports, ad hoc queries, etc.).

Linkage 8 (Subproblems 2 and 5).

There are two interdependencies making up this linkage, with a combined weight of 1.0. The focus of these interdependencies is the proration of personnel budgets for the production of periodic operating reports.

Linkage 9 (Subproblems 2 and 7).

This linkage includes two interdependencies, with a combined weight of 1.3. It focuses on the use of a hierarchical organization of object codes for facilitating the production of special reports.

Linkage 10 (Subproblems 2 and 8).

This linkage contains ten interdependencies, with a total weight of 3.8. All of these interdependencies have a clear common focus, namely, data commonality between requirements for operations reporting (Subproblem 2) and for planning (Subproblem 8). Although as pointed out earlier, planning data and budgeting data is not identical, there is enough commonality to generate numerous implementation-level interdependencies. For instance, some of the data required by the Dynamic Model (requirement 35 in Subproblem 8) may be obtained from various managers' Future Budgets (requirement 22, Subproblem 2) databases.

Linkage 11 (Subproblems 2 and 9).

This linkage contains two interdependencies, with total weight 1.0. Its focus is the data management issues common to Future Budget personnel data.

Linkage 12 (Subproblems 2 and 10).

This linkage contains 16 interdependencies, with a total weight of 6.8. All of the interdependencies within this linkage concern different aspects of data access commonality between the two subproblems. Eight of the interdependencies focus on databases common to ad hoc retrieval requests associated with operations monitoring, and similar requests associated with funds management. Another four interdependencies are related to databases common to operations monitoring, and to making effective use of fund accounts. Another three relate to similar databases common to standard report generation for operations monitoring and for fund management. Finally, one of the interdependencies represents the common need for access to other systems' data files.

Linkage 13 (Subproblems 2 and 11).

This linkage represents five interdependencies, with a total weight of 1.9. All five interdependencies pertain to the application of the facility for adding new data item types to currently existing databases, to the development of operations monitoring requirements.

Linkage 14 (Subproblems 3 and 4).

There is a single interdependency in this linkage, with a weight of 0.5. The focus of this link is mechanisms for speeding the delivery of Budgeting System information, in the form of standard reports, to system users.

Linkage 15 (Subproblems 3 and 6).

There are two interdependencies within this linkage, with a total weight of 0.7. Their common focus is the maintenance of database integrity and security by means of a transaction logging technique.

Linkage 16 (Subproblems 5 and 9).

There are two interdependencies in this linkage, with a total weight of 1.3. Their common focus is the conversion of personnel data between dollars and EFT.

Linkage 17 (Subproblems 6 and 9).

This linkage includes three interdependencies, with combined weight 0.9. Their focus is audit trail maintenence in the face of automatic system updating of certain data items.

Linkage 18 (Subproblems 6 and 10).

This linkage includes three interdependencies, total weight of 0.9. They all focus on the effecting of computer-based funds drafting.

Linkage 19 (Subproblems 6 and 11).

This linkage consists of a single interdependency, total weight 0.5. The linkage concerns the implementation of a data change log in a restructurable database.

Linkage 20 (Subproblems 7 and 8).

This linkage contains a single interdependency, with a weight of 0.5. It concerns the use of the object hierarchy for organizing the development of planning data for the Dynamic Model.

Linkage 21 (Subproblems 10 and 11).

The final linkage also includes but one interdependency, with a weight of 0.8. Its focus is the addition of fund purpose categorization information to the funds accounts.

* * * * *

This completes the description of the individual linkages between the design subproblems. Summary descriptions of the 21 inter-subproblem linkages are given in Table 4.4.

Figure 4.4 shows a complete description of the SDM-derived architecture for the new Budgeting System. Each design subproblem and linkage is labelled in an abbreviated fashion, based on the descriptions given in Tables 4.2 and 4.4.

In the final section of this report we briefly discuss certain broad issues that arise out of this architecture. We also summarize there the work to date and suggest some areas for further research.

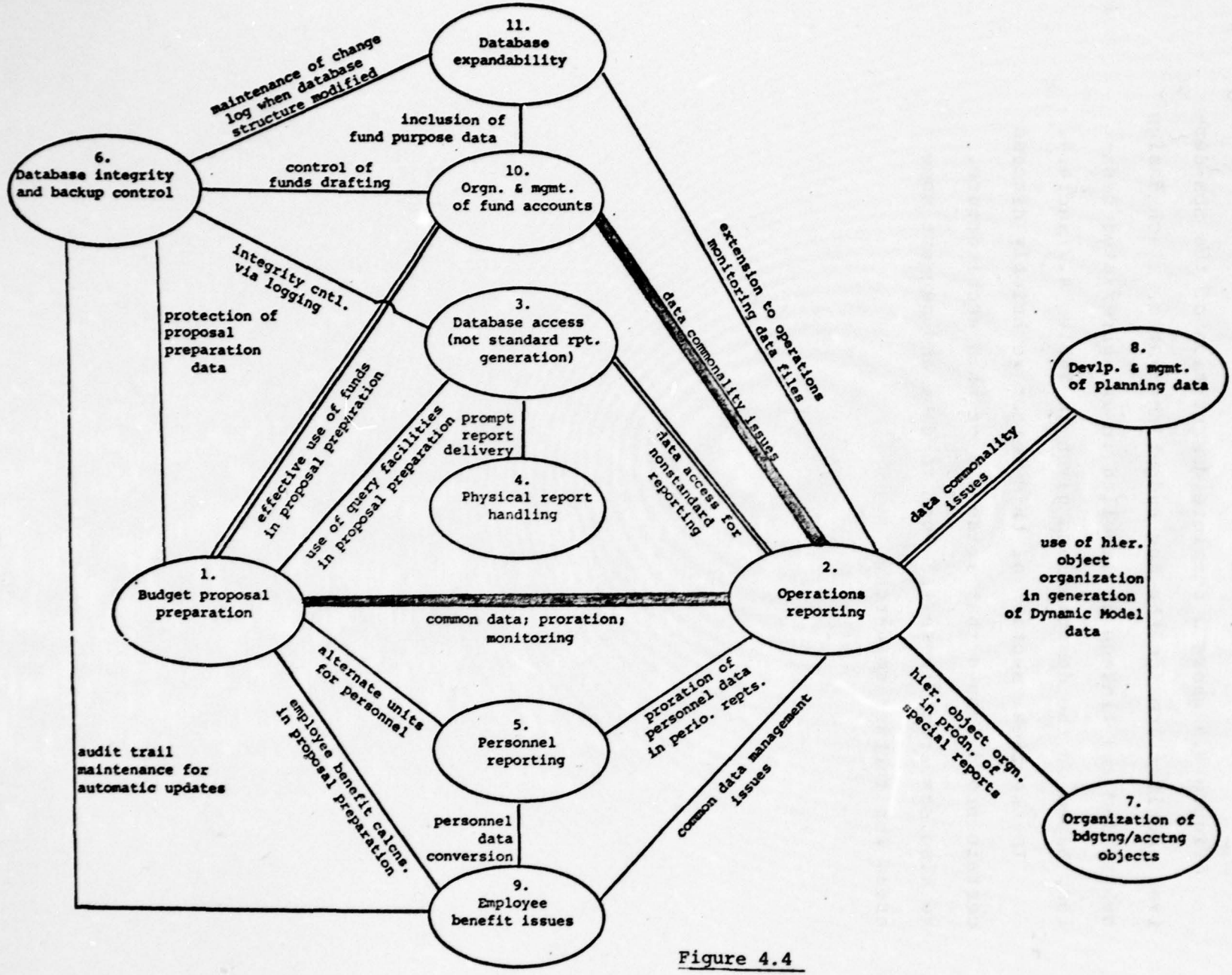


Figure 4.4

Complete description of the SDM architecture for the new Budgeting System

ID	Subgraphs	Summary Description
1	1,2	common databases; common processing viz. proration, monitoring.
2	1,3	training in proposal prep. use; proposal/ fund draft review and checking via query.
3	1,5	alternative units for personnel data.
4	1,6	protection of the security and integrity of proposal preparation data.
5	1,9	employee benefit calculations in proposal preparation.
6	1,10	effective use of funds in proposal preparation.
7	2,3	data access for nonstandard usage.
8	2,5	personnel data proration in periodic rpts.
9	2,7	use of hierarchical object organization in production of special reports.
10	2,8	operations reporting and planning data commonality.
11	2,9	common Future Budgeting/Personnel Budgeting data management issues.
12	2,10	data commonality: ad hoc retrieval, monitoring standard reporting, other systems.
13	2,11	extension of operations monitoring data files.
14	3,4	prompt report delivery.
15	3,6	use of logging to effect database integrity and security.
16	5,9	conversion of personnel data: dollars vs. EFT.

17	6,9	maintenance of audit trail in face of auto. updating of data elements.
18	6,10	effecting computer-based funds drafting.
19	6,11	maintenance of change log when database structure is modified.
20	7,8	hierarchy of object codes used to effect generation of Dynamic Model data.
21	10,11	addition of fund purpose categorization data to fund accounts.

Table 4.4

Summary Description of the Subproblem Linkages.

5. CONCLUSIONS.

The original objectives of this study were threefold:

1. to study the application of the Systematic Design Methodology in a real, ongoing design context;
2. to study the reactions of a group of real(9) system designers to the methodology, to begin to learn their views of its usefulness, effectiveness, etc.
3. to assist the Budgeting System design team in constructing an architecture for this new system.

As for the first point, the various steps of the SDM were able to be executed with little difficulty. As reported earlier, a substantial amount of time was spent initially in preparing the requirement statements. Also, the interdependency analysis phase consumed quite a bit of meeting time. However, the decomposition analysis and architectural interpretation were both relatively straightforward, and not particularly time consuming. This suggests that the time and effort invested early in the SDM effort pays off in terms of a "good" initial decomposition and easily interpretable architecture later on.

Such an observation is in general agreement with what other software design researchers have found in other contexts. Boehm, for instance, has estimated on the order of a

---

(9) as opposed to SDM researchers playing the role of system designers

3-to-1 payback to additional time invested in early design activities (Boehm 75). Also, the truth of this observation in the SDM context is verified by earlier applications carried out by other SDM researchers. Andreu (Andreu 77(a)) applied SDM to the design of a database management system. He adopted a set of government-issued DBMS requirement statements for use in his design. His first pass at building a system architecture resulted in a rather unsatisfactory decomposition, with a few large, unwieldy, hard-to-interpret subproblems. After "completing the requirements set" by studying the requirements statements carefully for missing requirements, ambiguous statements, etc., and making a number of additions and modifications, a second decomposition resulted in what Andreu argued was a much better architecture - smaller, more coherent subproblems arranged in a fashion he found much easier to interpret.

In contrast, in the present study we spent much more time in framing and refining the original requirement statements. In fact, the requirement specifications upon which the SDM statements were based was the result of over a year of study, analysis, interviews, etc. Also, the SDM version of the statements was given reasonable in-depth study over a number of iterations by both the system designers and the SDM researcher. It is most likely for this reason that the requirements decomposition and resulting architecture turned out to be as good as it did after a single "pass" of the SDM

analysis. With very few exceptions (to be discussed below) the design subproblems and linkages were clear and easy to interpret. All subproblems were found to have an obvious design focus, as described earlier. Similarly, the important design implications of the various inter-subproblem linkages were easily identified. Judged by this mixture of intuitive and explicit measures, SDM functioned well in guiding us to the identification of a good architecture for the new Budgeting System.

The second point concerns reactions of the Budgeting System designers to SDM. They expressed both positive and negative reactions to the analysis exercise, all of which were discussed earlier (see Section 3.3). In summary, the main negative reactions concerned the time required for the analysis, and some uncertainty about the overall value of the exercise (the latter occurred mostly at the outset). Both issues were tempered, of course, by an appreciation of the research nature of the study. The positive reactions concerned new design ideas, as well as clarification and improvement of current ideas, that emerged during the exercise; discovery of new ways of approaching the design task in general (e.g., separation of functional concerns from implementation issues); and their belief that the final architecture would be of assistance in the later detailed design efforts.

As for the final point, the eventual value of the Budgeting System architecture presented in the preceding section cannot be known at this time. Rather, it will be necessary for the SDM researchers to follow up this exercise in the future to learn what kind of impact this study might promulgate.

The study has provided a number of other insights, many of which were mentioned earlier in this report. The most important of these are summarized below.

1. The design architecture that emerged from our work did prove to be relatively "clean" (high strength, low coupling). However, a few minor points might bear additional investigation by the system designers. For instance, requirement 64 was found not to have an obvious "home" in any subproblem. This may suggest that either certain interdependencies between it and other requirements were missed during the earlier analysis, or possibly that other requirements more closely associated with requirement 64 are missing from the requirement set.

2. A second minor decomposition issue concerns the size of Subproblem 2. As discussed in Section 4.2 earlier, there are good reasons for the relatively broad scope of this subproblem. The operations reporting function is central to the Budgeting

System, hence we should expect this subproblem to encompass a larger collection of requirement statements than many of the others. The centrality of the subproblem is further evidenced by noting that it has eight linkages to other subproblems - substantially more than any of the others (see Figure 4.4). The centrality of this subproblem should serve as a signal to the system designers that perhaps the detailed design ought to also center on the implementation of these requirements. Also, in general the presence of a large subproblem such as this in a decomposition should be carefully studied, as it may suggest possible improvements to the decomposition. Andreu found the occurrence of especially large, heterogeneous subproblems to be "caused" by in incomplete or poorly framed requirements set. Also, it could be that certain interdependency assessments are missing or in error. While they will not be further investigated here, these possibilities are worth some study by the system designers in the future.

3. A third summary point is that the SDM techniques used in this study seemed to function rather well. The use of a three-way breakdown for specifying interdependency weights should be judged quite effective in practice: a threefold distinction

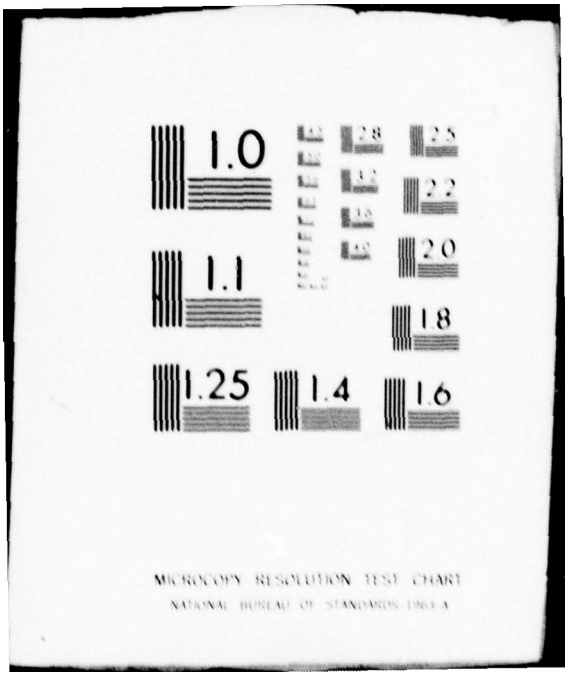
could be made easily by the designers, and the need for finer detail rarely arose. Other mechanisms - the interdependency data form, use of WSCRIPT to manage the requirement statements, etc. - worked well. The decomposition package also functioned effectively. A number of ideas for marginal improvements to the package arose in the course of its application to the Budgeting System problem, but these will not be elaborated on here.

4. One lesson that came through quite clearly in this exercise is the important role data linkages play in determining requirement interdependencies in this kind of system design. In a number of cases, part or all of the common implementation issues tying a set of requirements together within a subproblem were common databases required for their implementation. Also, such data commonality formed the basis of the linkage between various subproblems. It is interesting to note that in the previous SDM application exercises this important role of data commonality was not evidenced. This is not too surprising since systems like the Budgeting System are much more concerned with capturing, processing, reporting, and otherwise dealing with various databases than would be "systems" software such as a DBMS or an operating

AD-A071 748 ALFRED P SLOAN SCHOOL OF MANAGEMENT CAMBRIDGE MASS C--ETC F/G 9/2
ARCHITECTURAL DESIGN OF A NEW M.I.T. BUDGETING SYSTEM: AN APPLI--ETC(U)
JUN 79 S L HUFF N00039-78-G-0160
UNCLASSIFIED CISR-P010-7906-11 NL

2 OF 2
AD
A071748

END
DATE
FILMED
8-79
DDC


1.0
1.1
1.25
1.4
1.6
2.8
2.5
2.2
2.0
1.8
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

system, at least at the architecture level. However, while perhaps not so surprising in retrospect, this observation should serve to make the importance of database organization for the Budgeting System stand out during future design and implementation work.

While still a research project, the Systematic Design Methodology is proving its effectiveness in aiding system architects to organize and manage the many and diverse requirements typical of complex systems design. This study has suggested new improvements that may be made to the methodology, while again confirming its fundamental soundness and value.

REFERENCES

Andreu, R.C., and S. E. Madnick: "An Exercise in Software Architectural Design: From Requirements to Design Problem Structure", Internal Report P010-01-05, November 1977(a).

Andreu, R.C., and S. E. Madnick: "Completing the Requirements Set as a Means Towards Better Design Frameworks: A Follow-up Exercise in Architectural Design", Internal Report P010-01-06, MIT Sloan School of Management, December 1977(b).

Andreu, R. C.: A Systematic Approach to the Design and Structuring of Complex Software Systems, PhD. Thesis, Sloan School of Management, M.I.T., Cambridge, Mass. 1978.

Alexander, C.: Notes on the Synthesis of Form, Harvard University Press, 1964.

Aron, J.: The Program Development Process - Part II: The Development Team, preliminary draft version, Addison-Wesley Publishers, June 1977.

Boehm, B.: "Software and Its Impact: A Quantitative Assessment", Datamation, vol. 19, no. 5, May 1973.

DeWolf, B.: "Requirements Specification and Design for Real-time Systems: A Problem Statement", IR&D Memo No. 4, C. S. Draper Labs., Jan. 1977.

Folinus, J., et. al.: "Virtual Information in a Database System," Report CISR-3, Sloan School of Management, M.I.T., Cambridge, Mass., July 1974.

Gutirrez, M., and U. Schirmer: "Description and Analysis of the M.I.T. Budgeting Process," MS Thesis, Sloan School of Management, Cambridge, Mass., May 1977.

Herzog, F., and G. Matson: "The M.I.T. Budgetary Process: A Descriptive Model," Internal Report, M.I.T. Office of Administrative Information Systems, Cambridge, Mass., 1974.

Holden, Timothy: "A Systematic Approach to Designing Complex Systems: Application to Software Operating Systems", Internal Report P010-7805-05, M.I.T. Center for Information Systems Research, May 1978.

Horowitz, E., et. al.: Practical Strategies for Developing Large Software Systems, Addison-Wesley, May 1975.

Hudock, K.: "Report on User Needs for a New M.I.T. Budgeting System," Internal Report, M.I.T.Office of Administrative Information Systems, Cambridge, Mass., 1978.

Huff, S. L., and S. E. Madnick: "An Approach to the Construction of Functional Requirement Statements for System Architectural Design", Internal Report No. P010-7806-06, June 1978.

Huff, S.: "Analysis Techniques for Use With the Extended SDM Model," Technical Report 9, MIT Sloan School of Management, February 1979(a).

Huff, S.: "A Normative Cost-Benefit Analysis of the Systematic Design Methodology," Technical Report 10, Sloan School of Management, M.I.T., February 1979(b).

IBM: "Information Management System: Virtual Storage," IBM Manual GH20-1260-1, IBM Corp, Armonk, New York, 1974.

Jackson, M.: Principles of Program Design, Academic Press, 1975.

Martin, J.: Principles of Database Organization, Prentice-Hall Inc, 1976.

Myers, G.: "Characteristics of Composite Design", Datamation, vol. 19, no. 9, September 1973.

Parnas, D.: "On the Criteria to be Used in Decomposing Systems into Modules", Comm. of the ACM, vol. 15, no. 12, Dec. 1972.

von Letkemann, H., B. Shaw, et. al.: "Budget System Functional Requirements," and "Supplement to Functional Requirements," Internal Reports, M.I.T. Office of Administrative Information Systems, September 1978.

Appendix A

EXAMPLE OUTPUT FROM THE IBM 3800 PRINTER.

On the following page is a sample of the output obtainable from the IBM 3800-type printer.

MONTHLY ANALYSIS

SUPERVISOR D T OTHERWAY
ROOM E40-250

ADDRESSEE F H FINK
ROOM E40-211

 AS OF DATE 02-28-77

DEPARTMENT NAME: CENTER FOR ALTERNATE LIFESTYLE
DEPT.NO.: 046900
EFFECTIVE: 10-01-76
EXPIRES: 09-30-78
ACCOUNT NAME: CELESTIAL NAVIGATION OF TADPOLES
ACCT. NO.: 84559

SPONSOR NATIONAL FROG FOUNDATION
REFERENCE 7602054-PRA
PARENT ACCT 84545

OBJ. CODE	DESCRIPTION AND NOTES	PRO-RATE CODE	ACTUAL CURRENT MONTH	ACTUAL FISCAL YTD	PROJECTED REMAINING F.Y. BUDGET.	PROJECTED F.Y. TOTAL (FYTD)+(REM)	F.Y. BUDGET AUTHORIZED 02-11-77	CHNG	FISCAL YEAR VARIANCE (BUD)-(PROJ)	NOTE	CUMULATIVE AMOUNT	TOTAL AUTHORIZED
	EXPENDITURES											
	SALARIES AND WAGES E.F.T.											
214	OTHER ACAD. STAFF-ON 2.3	12	1,154	1,904	3,600	5,504	10,800		5,296	*	1,904	5,602
320	SECRETARIAL & CLER-ON .8	12			1,872	1,872	5,616		3,744	*		7,488
346	TECH OR ADMIN SUPT-ON .8	12		96	934	1,030	2,801	1	1,771	*	96	5,602
988	TOTAL SUBJ TO E.B. 2.3	10	1,154	2,001	6,406	8,406	19,217		10,811	*	2,001	51,269
350	GRAD STUDENT STAFF-ON .0				1,295	1,295	3,453		2,158	*		10,360
990	TOTAL SLRY & WAGES 2.3	10	1,154	2,001	7,701	9,701	22,670		12,969	*	2,001	61,629
	EMPLOYEE BENEFITS ON OFF											
401	BILLING RATES 24.50% 28.50%	18	283	490	1,887	2,059	4,710		2,651	*	490	12,561
989	TOTAL SALARIES, WAGES & E B	10	1,437	2,491	9,588	11,760	27,380		15,620	*	2,491	74,290
	OPERATING EXPENSES											
415	TRAVEL	01										1,000
419	MATERIALS AND SERVICES	12		81	1,031	1,112	2,319		1,207	*	81	6,184
523	XEROX EXPENSE	01		34		34			34-		34	
818	TEL-TOLL CALLS	01	19	34		34			34-		34	
991	TOTAL OPERATING EXPENSES	10	19	149	1,031	1,180	2,319		1,139	*	149	7,184
	COMPUTATION EXPENSES											
896	IPC CHARGES	12	140	349	167	516	375		141-		349	1,000
899	TOTAL COMPUTATION EXPENSS	10	140	349	167	516	375		141-		349	1,000
	OTHER CHARGES											
901	OTHER CHARGES	17										3,000
839	TOTAL OTHER CHARGES	10										3,000

SAMPLE

Appendix B

INITIAL BUDGETING SYSTEM FUNCTIONAL REQUIREMENTS AS PREPARED BY THE SYSTEM DESIGNERS.

1. Automate as many manual procedures as feasible to save time and effort

2. Provide in the Chart of Accounts the following for all fund accounts:

   a) Coding for Principal - Endowment, Quasi-endowment, or Term Endowment

   b) Coding for Income or current funds - Unrestricted, Restricted, Designated, or Restricted and Further Designated.

   c) Update the 60-character 'Fund Purpose' field

3. Collect and store planning data contributed by the senior managers

   a) Data must be in reasonably uniform, useful format

   b) Data should include short range (Next fiscal year) and long range (3 to 5 years) plans

   c) The report of the senior managers contained in the 'Report of the President and the Chancellor' should refer to and be consistent with the short range plan presented prior to the beginning of the fiscal year.

   d) Planning data would be available to the Dynamic Model (or its replacement)

4. Provide for collecting, storing and reviewing details of special financial agreements made among managers. Details could be picked up when drafts are processed. These might be input at time drafts are made.

5. Provide for budgeting and reporting by E.F.T. as well as dollars. An interface with the Payroll System may be necessary.

   a) Automate system where possible so that a person may be budgeted either by E.F.T. or dollars and provide a method for one to generate the other

   b) Allow for either actual or average salaries to be used in budget proposals.

   c) Provide checks to ensure that each person is not budgeted more than 100% E.F.T.

6. Provide for producing reports in units of man-weeks, man-months or man-years

7. Provide for additional object codes to be summaries of other object codes as necessary

   a) Use summary codes for subtotals on reports or for reporting only these subtotals

   b) Explore usefulness of summary codes that would correspond with Billing Codes

8. Review Object Code descriptions to ascertain their current applicability

9. Provide support for special object codes for use by each department. The descriptions for these codes would be supplied by the using departments, and they would subtotal to the appropriate summary object codes.

10. Reports must be easier to handle and store. Both the IBM 3800 and Xerox 9700 Printers would solve this problem through the use of 8 1/2" by 11" size paper without sacrificing data capacity.

11. Provide for sharing budget data with users of other systems and for use of the files of other systems by the Budget System (e.g. Gift System, ARS, Payroll, Purchasing, etc.)

12. Provide for as much early recognition of potential problems as possible so that corrections can be made in time to prevent them

    a) Provide easy way to project income and expenses over the fiscal year on a month by month basis so as to provide a ready measure of actual performance vs. budget.

b) Provide way to flag amounts or items when predetermined tolerances or dates are exceeded

13. Provide and maintain access to data:

a) Chart of Accounts

b) Future budget data by month by object code within account

c) Current fiscal year budget data by month by object code within account

d) Last fiscal year budget data by month by object code within account

e) Current fiscal year actual data by month by object code within account

f) Last fiscal year actual data by month by object code within account

g) Historical data, up to 10 years of budget and actual data by object summary within account

h) Salary and other data required for proposal preparation

14. Promote optimal use of fund accounts so as to conserve general monies

a) Provide directory (or directories) and an application index of funds so as to readily show how they can be applied. This would require collection and maintenance of abbreviated text of fund description and donor's intentions.

b) Enhance existing reports (X52, X53 and/or X56) with available data so as to make them more useful in applying funds.

c) Provide for production of a report in X52/X53 format showing 10 years of historical data.

d) Explore other ways to promote use of funds when it is optional, such as matching fund expenditures with a certain amount of General money.

15. Support monitoring of operating budget

a) Budget vs. actual

b) 'Operating gap'

16. Support, improve or replace the following reports or items of information:

a) Printed Budget

i) In detail by account within departments and areas of responsibility

ii) In 'Schedule A' format for inclusion in the Treasurer's Report

iii) In functional format

b) Schedules for the Treasurer's Report

c) Indirect Cost Recovery Percentage based on CAO Studies

d) Analyze effects of potential 'dollar budgeting' decisions, such as 1% salary change, etc. Be sure to provide for changing scholarship, fellowship and stipend rates when changing tuition.

e) MITOP

f) Dynamic Model

i) Provide for automatic interrelationship so that when data changes the subsequent effects are shown

ii) Provide for ease of rerunning with changes in variables and assumptions to answer 'what if' questions

iii) Explore use of Boeing's Executive Information System or other packages to support modeling

g) Periodic Summary of Operations

h) Budget Authorizations and Changes, and explanations of the changes, including dollar budgeting.

i) Provisional and approved Budget Authorizations

ii) Changes in authorized amounts or allocations and explanations of same, including dollar budgeting

i) Gross and net effect of budget changes, including, but identifying, 'dollar budgeting'

j) Budget vs. Actual Reports (X80, X83, X84)

k) Detailed Transaction Report

   i) Print account title on DTR

   ii) Include detail of Purchase Order Commitments

   iii) Provide more information in description and reference fields so as to facilitate tracking expenses

   iv) Expand data content to include YTD and cumulative data

   v) Do not produce DTR in months when there is no activity for an account

l) Monthly Statement

   i) Consider showing 'Travel Outstanding' immediately following 'Travel' and subtotaling them

   ii) Supply meaningful Purchase Order Commitment data

m) List of accounts about to expire

n) Budget proposal forms and supporting documents

o) Area of Responsibility Report

p) Department Profiles

q) Report of Fund Drafts

r) Physical Plant Summary

17. Supply new reports as required for fiscal planning and budgeting

   a) Analysis of faculty support, in both E.F.T. and dollars, contributed by laboratories to academic departments

   b) Report on research type, discipline and function so as to satisfy both NSF and MIT requirements

c) Monthly Analysis

i) Determine if Monthly Analysis should be published in place of or in addition to Monthly Statement

ii) Investigate rounding of dollar amounts to nearest $1

iii) Investigate feasibility of not publishing Monthly Analysis for months in which there is no activity in an account

iv) Provide for including or excluding certain data depending on user requirements, i.e. eliminate billing and fiscal year-to-date data from report to principal investigator, etc.

v) In forms design try to show subsections by rounding tops of column heads

vi) Consider showing 'Travel Outstanding' immediately following 'Travel', and subtotaling them

vii) Print account numbers in lower right corner for easy lookup when reports are filed in a notebook

viii) Print notes to show special restrictions.

ix) Provide for flexibility in format for content (optional columns)

x) Print notes that describe budget changes

xi) Supply meaningful Purchase Order Commitment data

d) Summary Analysis for:

i) Parent Accounts

ii) Departments and subdepartments

iii) Schools

iv) Areas of Responsibility

v) The Institute

vi) Principal Investigator

vii) Research Type, Discipline and/or function

viii) Other subdivisions as required

e) Terminal formats for entering budget proposals

f) Budget Projection - Month by month projection by object codes for one or a group of accounts.

g) Additional reports used by certain departments, such as K. Keays series

18. On Personnel Action Form add a box to indicate whether person hired is a replacement or an addition.

19. Support Special reports for budget-related activities

a) Standard reports at non-standard times

b) Standard reports for non-standard periods

i) Contract period

ii) Sponsor's fiscal year

c) Standard data in non-standard formats

d) Report-writer language for fully customized reports. This language must be easily learned and used.

20. Support for on-line operations with budget database

a) 'Menu' for standard inquiry series

b) Inquiry language for special use

c) Support for on-line requests for reports to be printed either on terminal or at remote printer

21. Provide data security and recoverability

a) Protect sensitive data against unauthorized use by checking and logging indentity of user and, possibly, by encoding data

b) Prevent data from being changed by unauthorized persons, access would be 'read only' except to its owner

c) System must provide data integrity through logging of changes and capability of reversing them

d) Provide adequate file backup procedures

22. Provide a simplified proposal preparation procedure that will support both on-line and manual preparation of budgets.

23. Investigate proposal preparation using primarily summary object codes.

a) Standard MIT monthly statement summary object codes for subtotals

b) Billing summary object codes

24. Provide for review of budget proposals and changes by the Budget Office in simplified ways

a) Investigate feasibility of manually-prepared machine-readable budget proposal worksheets

b) Provide for review and acceptance of proposals prepared either manually or on-line

c) Provide maximum effective amount of computer editing of budget proposals

d) Provide check to be sure proposals are within target amount

e) Compare actual E.F.T. and head count against allowances

f) Provide check to be sure every open account has a proposal

g) Be able to tell status of every proposal

25. Identify 'base general' in budget

26. Provide for changing Employee Benefit amounts when changes are made affecting the amount of Salary and Wages budgeted

27. Encourage the use of program budgeting while still supporting other effective budgeting techniques currently in use

28. Provide logical integrity of budget data by assigning ownership and responsibility for each

data element. Administrators should be able to change certain elements or allocations on their own authority, whereas others should require Budget Office approval

29. Provide a system for tracking research proposals so as to show whether they are accepted or rejected, what amount of funding is made available, funding agency, principal investigator, length of contract, special restrictions, and other appropriate information. Record OSP proposal number on 001 form.

30. Support the establishment and use of a system of Discipline/Function codes for research projects

31. Eliminate the need for certain departmentally-produced reports by making available either standard or special reports.

32. Promote simplification of the budgeting and financial planning operations

33. Provide documentation and audit trail required for follow-up of discrepancies in system, operational or user areas.

34. Support handling of all required aspects of special items such as:

    a) Nonrecurring equipment

    b) Carryforward amounts

    c) Sabbatical leaves

    d) Drafts

    e) Reserves

    f) Other special requests

35. Support Fund Drafts by computer via on-line and batch as well as manual (log sheet) requests from user departments. Use on-line checking by Budget Office where feasible.

36. Provide for recording joint or non-standard support for an account

37. Determine desirability and feasibility of encumbering salary and wage budgeted amounts.

38. Establish data base to support budget activities as well as ARS and other data or systems

39. Investigate the feasibility of updating actual income and expense data more frequently than once a month.

40. Review system of fund purpose codes to see if they could be made more beneficial to both gift system and fund users.

41. Provide for communication between Budget System and Gift System.

42. Provide for additional data and types of data to be stored as requirements occur

    a) Provide for an open-ended system of descriptors for accounts or objects within an account to carry whatever supplementary data may be needed by users. This would include:

        i) Data on special funding and non-recurring expenses

        ii) Indicators as to Functional Summary categories

        iii) Complete set of applicable Donor Purpose codes for fund accounts

    b) Provide for access to data via the special descriptors

43. Provide for discussion of all projected changes with affected users whenever feasible

44. Provide formal training for users when system is introduced and periodically thereafter

45. Provide, maintain and distribute adequate documentation for all system users.

46. Support various Employee Benefit Codes and Overhead Recovery Rates as appropriate

    a) Ensure that data is available to show employee benefit and overhead recovery rates appropriate to the accounting period.

    b) Support individusl employee benefit rates to accommodate personnel from other universities who work on projects at M.I.T., such as the

consortium for the Center for Materials Research in Archaeology and Technology

47. Speed up delivery of reports to users

48. Explore possibility of accounting cutoff at the end of the month

Appendix C

FINAL BUDGETING SYSTEM FUNCTIONAL REQUIREMENTS AS USED IN THE SDM ANALYSIS.

1. Fund accounts will be categorized by fund purposes.

2. Fund accounts can be categorized by principal type.

3. Fund accounts can be categorized by income type.

   COMMENT:

   Principal types may include endowment, quasi-endowment, and term endowment.

   Income types may include: Unrestricted, Restricted, Designated, or Restricted and Further Designated.

4. Each fund account will be described via abbreviated text description.

   COMMENT:

   The current 60-character fields may be used for this purpose.

5. Short-term and long-term planning data will be provided by Senior Managers.

   COMMENT:

   Senior Managers are: Deans, Department Heads, Lab Directors, and Vice Presidents.

6. Planning data will be provided in a standardized format.

   COMMENT:

   Department profile format.

7. Data regarding special financial arrangements made by managers will be maintained.

COMMENT:

Could be between managers or between fund donors and managers.

8. Personnel budgets can be developed in dollars.

COMMENT:

Either average or actual figures.

9. Personnel budgets can be developed in EFT.

10. There will be a facility for converting salary/wage information between dollars and EFT.

COMMENT:

This conversion should be as automatic as possible.

11. Certain objects may be logically related to groups of other objects.

COMMENT:

For example, summary object codes.

12. A particular object may belong to multiple object groups.

COMMENT:

For example, certain codes may be reserved as summary codes for specific groups of other object codes. Summary codes might include subtotal information.

13. Manpower can be reported in alternative units.

COMMENT:

For instance, dollars, man-days, man-months, man-years.

14. There will be special object codes available for use by each department.

COMMENT:

Each department would determine its own categorizations.

Instance: additional subdivisions on travel: Travel to LA, Travel to Washington, etc.

15. Reports will be physically easy to handle.

COMMENT:

3800 printer would help to do this by increasing data capacity per page.

16. Budgeting and planning data can be accessed readily by other systems.

17. The budget system can access directly data in other systems' files.

COMMENT:

Including ARS, Payroll, Gift systems.

18. There will be a general comparison reporting capability.

COMMENT:

May be budget-versus-budget or budget-versus-actual.

May be for diiferent time periods (e.g., a particular week this year versus same week last lear).

Other examples would be: one department versus rest of school; comparisons between budgets of different principal investigators.

19. Items exceeding prespecified bounds can be highlighted.

20. Chart of Accounts and associated supplementary data will be accessable by Budget System.

21. Current fiscal year budget data will be maintained.

22. Future Budget data will be maintained.

23. Last fiscal year Budget data will be maintained.

24. Current fiscal year Actual data will be maintained.

25. Last fiscal year Actual data will be maintained.

COMMENT:

In general, income and expense data will be accessable by month and object code within account.

26. Historical Budget data will be maintained for up to 10 years.

COMMENT:

May be aggregated; will be off-line.

27. Historical Actual data will be maintained for up to 10 years.

COMMENT:

May be aggregated; will be off-line.

28. Data required for budget proposal preparation and not available elsewhere will be maintained.

COMMENT:

e.g., salary data from payroll system; target data.

29. Budgeted income and expense data will be prorated automatically on a month-by-month basis.

COMMENT:

Prorations can be selected from standard profiles.

Special proration profiles may be supplied by managers.

There will also be a "no proration" alternative.

30. Information to facilitate the effective use of fund accounts will be available.

COMMENT:

Provide directory (or directories) and an application index of funds so as to readily show how they can be applied. This would require

collection and maintenance or abbreviated text of donor's intentions and fund description.

Enhance existing reports (X52, X53 and/or X56) with available data so as to make them more useful in applying funds.

Provide for production of a report in X52/X53 format showing 5 years of historical data.

Explore other ways to promote use of funds when it is optional, such as matching fund expenditures with a certain amount of General money.

31. Monitoring of the operating budget will be supported.

COMMENT:

e.g., budget-versus-actual reports; operating gap analysis.

32. Various Future Budget reports will be generated.

COMMENT:

Support, improve, or replace the following reports:

Printed budget:

In detail by account within departments and areas of responsibility.

In 'Schedule A' format for inclusion in Treasurer's report.

In functional format.

Physical plant summary.

Department profiles.

Budget Authorizations and Changes, and explanations of the changes, including dollar budgeting.

Provisional and approved Budget Authorizations.

Changes in authorized amounts or allocations and explanations of same, including dollar budgeting.

Gross and net effect of budget changes, including, but identifying, 'dollar budgeting'.

Budget proposal forms and supporting documents.

33. Periodic operating reports for each account will be generated.

COMMENT:

Reports will include current budget and current actual-to-date data.

Modified detailed transaction report (ARS).

Print account title on DTR.

Include detail of Purchase Order Commitments.

Provide additional information in description and reference fields so as to facilitate tracking of expenses.

Expand data content so as to include YTD and cumulative data.

Do not produce DTR in months when there is no activity on account.

Monthly statement or its replacement (monthly analysis).

Consider showing 'travel outstanding' immediately after 'travel,' and subtotaling them.

Supply meaningful purchase order commitment data.

Budget versus Actual reports (X80, X83, X84).

34. Various special-purpose (non-periodic) reports will be generated.

COMMENT:

Schedules for Treasurer's Report.

Indirect cost recovery percentage, based on CAC studies.

MITOP.

Periodic Summary of Operations.

List of accounts about to expire.

35. The data necessary for use by the Dynamic Model will be generated.

COMMENT:

The model will support automatic interrelationships of variables.

36. Ad hoc requests for information will be supported.

COMMENT:

For example, analyzing the effects of potential 'dollar budgeting' decisions, such as 1 percent salary changes, etc.

37. Various funds reports will be generated.

COMMENT:

In particular, the report on Funds drafts.

Also Funds Schedule for Treasurer's Report.

38. The system will have access to certain personnel hiring data.

COMMENT:

Monitoring head count allowances.

Add box on Personnel Action form to indicate whether person hired is a replacement or an addition.

39. Certain budget report data items can be optionally included or excluded from Monthly Analysis Report as specified by the user.

COMMENT:

e.g., eliminate billing and fiscal YTD data from report to principal investigator.

40. Variations of standard Budget System reports will be developed as requested.

COMMENT:

Analysis of faculty support, in both F.F.T. and dollars, contributed by laboratories to academic departments.

Report on research type, discipline and function so as to satisfy both NSF and MIT requirements.

41. New budget reports will be developed as required.

COMMENT:

e.g., Monthly Analysis:

Determine if Monthly Analysis should be published in place of or in addition to Monthly Statement.

Investigate rounding of dollar amounts to nearest $1.

Investigate feasibility of not publishing Monthly Analysis for months in which there is no activity in an account.

Provide for including or excluding certain data depending on user requirements, i.e. eliminate billing and fiscal year-to-date data from report to principal investigator, etc.

In forms design try to show subsections by rounding tops of column heads.

Consider showing 'Travel Outstanding' immediately following 'Travel', and subtotaling them.

Print account numbers in lower right corner for easy lookup when reports are filed in a notebook.

Print notes to show special restrictions.

Provide for flexibility in format for content (optional columns).

Print notes that describe budget changes.

Supply meaningful Purchase Order Commitment data.

42. There will be a simple report-writing facility.

43. Users can develop their own special reports using the report writing facility.

44. There will be an on-line menu-oriented query facility.

45. There will be an on-line ad hoc query facility.

46. Reports generated on-line can be directed to the system printer or to users' printer/terminal.

47. Identity and activity of users will be logged.

    COMMENT:

    Should be provided by DBMS.

48. Data items can be accessed only by permissable users.

49. Data items can be changed only by their owner.

50. There will be a set of permissable users for each data item.

51. Each data item will have a unique owner.

52. Data items can be encoded for security.

53. There will be a log of all database changes.

54. There will be a file backup facility.

55. The database's integrity can be restored using backup files and change log if necessary.

56. Budget proposals can be prepared manually.

57. Budget proposals can be prepared on-line.

58. Budget proposals will be automatically checked and edited to the extent possible.

    COMMENT:

    Every open account must have an associated proposal.

    EFT cannot exceed 100 percent per person.

59. There will be controlling limits on amounts in proposed budgets and budget changes.

    COMMENT:

Check that proposals are within target amount, or within sponsor's limit.

Compare actual EFT and head count against allowances.

May be desirable to have controls on summaries also.

60. Budget proposals will be reviewed by the budget office and/or OSP.

61. Budget changes will be reviewed by the budget office and/or OSP.

62. Sources of funding for each account will be identified.

COMMENT:

Identification information may be included in budget account record.

63. Budgeted employee benefits will be changed automatically following changes in budgeted salary and wage amounts or EB rates.

64. All currently used budgeting techniques will be supported.

COMMENT:

Including line item budgeting, program budgeting, and task-oriented budgeting.

System should promote program budgeting.

65. Research proposal information can be stored, updated, and accessed.

COMMENT:

Provide various kinds of information for tracking research proposals to show whether they are accepted or rejected, what amount of funding is requested and made available, funding agency, principal investigator, length of contract, special restrictions, and other appropriate information. Record CSP proposal number on 001 form.

66. Research accounts and proposals will be categorized by type, discipline, and function.

67. There will be documented audit trails for determining system discrepancies.

68. Required aspects of non-recurring expenses will be supported.

    COMMENT:

    Concerns primarily sabbatical leaves, drafts, carryforward amounts, and nonrecurring equipment.

69. Fund drafts can be performed on-line.

70. Fund drafts can be performed in batch mode.

71. Fund drafts can be checked and approved on-line by Budget Office.

    COMMENT:

    Check may be done by Budget Office, or the responsible officer.

72. Additional data item types can be added to accounts or objects within accounts.

73. New data items can include or refer to supplementary data needed by users.

74. Formal training in the use of the system will be provided to users.

    COMMENT:

    Training and use documentation will be made available to legitimate system users.

75. Non-standard employee benefit calculations will be supported.

    COMMENT:

    Support individual employee benefit rates to accommodate personnel from other universities who work on projects at MIT (e.g., Consortium for Materials Research in Archealogy and Technology).

76. Overhead recovery rate calculations will be supported.

77. Standard periodic reports will be produced and distributed to users as quickly as possible.

COMMENT:

Minimize time between cutoff date and report receipt.

3800 printer will help by shortening printout time and by printing in distribution sequence.

Appendix D

FORM USED IN GATHERING INTERDEPENDENCY DATA.

The data form shown on the following page was used for gathering the interdependency data during the interdependency analysis phase of the study.

INTERDEPENDENCY ASSESSMENT SYSTEM: _____

FR	TO	WT	REMARKS	FR	TO	WT	REMARKS

Appendix E

BUDGETING SYSTEM REQUIREMENT INTERDEPENDENCIES.

FR	TO	WT	DESCRIPTION
1	4	S	Text description will reinforce and describe the categorization.
1	17	A	Fund purpose data may be stored elsewhere.
1	20	A	Fund purpose data may also be in Chart of Accounts.
1	30	S	Fund purpose code is a important instance of "effective-use" information.
1	36	W	Possible "fund purpose" report.
1	37	W	Possibly want to include fund purpose information.
1	58	A	Check budget proposals regarding fund purpose.
1	60	A	Reviewer would check fund purpose for consistency.
1	71	W	Can be checked for consistency.
1	72	S	May want to add new purposes.
2	4	S	Text description will reinforce and describe the categorization.

2	17	W	Fund purpose data may be stored elsewhere.
2	20	A	Chart of Accounts contains fund accounts.
2	30	S	Principal type is critical effective use information.
2	36	W	Possible fund report.
2	37	A	Information to be included in fund reports.
3	4	S	Text description will describe and reinforce categorization.
3	7	A	Often have special income restrictions.
3	17	W	Gift system is source for fund account data.
3	19	A	Accumulated income important to monitor.
3	20	A	Carried in Chart of Accounts.
3	30	S	Income type important regarding how spent.
3	36	A	Likely fund report.
3	37	S	Possibly want to include fund purpose information here.
4	17	A	Other systems may need to access description data.
4	30	S	Fund purpose description used in directory entry.
4	36	W	Text description likely target of ad hoc requests.
4	37	S	Text description would be included in many reports.
5	6	S	Use and capture of planning data related to format.

5	22	S	Related information sources.
5	34	A	Might want to develop projection reports.
5	35	S	Major purpose of planning data is to provide DM input.
6	22	W	Common formatting issue.
6	34	W	Summary planning reports possibly contingent on planning data format.
6	35	A	Format affects what can be requested.
7	30	A	Special arrangements for funds.
7	37	W	May want to report information regarding special arrangements.
7	58	A	May be able to automate checking to include SFA.
7	59	A	May be limits or controls on SFAs.
7	60	W	SFAs are grounds for examination.
7	62	S	Routine examinations.
7	68	S	An SFA is a special item of importance.
7	71	W	SFAs would need to be checked.
8	10	S	Common conversion issue.
8	13	A	Common conversion issues.
8	29	A	Proration of personnel expenses important issue.
8	63	S	Employee benefits developed from personnel budgets in dollars.
8	75	S	Employee benefit calculations need personnel information in dollars.
9	10	S	Common conversion issue.

9	13	S	EFT required for certain reporting units.
9	29	A	Proration of personnel expenses important issue here.
9	33	A	Standard reports include manpower.
9	38	W	Need EFT to properly monitor headcounts.
9	59	W	One control item.
10	13	S	Common conversion issues.
10	28	A	Budget proposal data may need conversion facilities.
10	38	W	May need conversion facilities to make effective use.
11	12	S	Common logical relationships issue.
11	14	A	Special codes have to summarize correctly.
11	34	A	Logical relationships used in summarizing.
11	35	A	Model uses mostly summary data, and logical relationships define certain summarizations.
12	14	A	Department summary codes need logical groupings.
12	34	S	Summarizations defined in logical groupings.
15	77	S	Common preparation issue - easier handling makes for faster delivery.
16	48	A	Allowable accesses must be controlled for other systems as well as individuals.
16	49	A	Need change protection as regards other systems.
16	52	W	Other systems may need encription key access.
17	20	S	Budget system will need access to Chart data.

17	69	W	Need link to Funds system.
17	71	W	Need Funds system link.
18	19	S	Comparisons indicate items to be highlighted.
18	22	A	Data used in comparisons.
18	23	A	Data used in comparisons.
18	24	A	Data used in comparisons.
18	25	A	Data used in comparisons.
18	26	W	Data used in comparisons.
18	27	W	Data used in comparisons.
18	29	S	Prorating generates detailed information for doing comparisons.
18	31	A	Comparisons necessary for monitoring.
18	32	A	Comparisons included in budget reports.
18	33	A	Comparisons included in periodic analysis reports.
18	34	A	Some comparisons included in summary reports.
18	39	A	May include comparisons.
18	41	A	May include comparisons.
20	22	A	Related data maintainance issue.
20	23	A	Related data maintainance issue.
20	24	A	Related data maintainance issue.
20	25	A	Related data maintainance issue.
20	31	A	Data used in monitoring.
20	32	A	Data is source for reports.
20	33	A	Data is source for reports.
20	34	A	Data is source for reports.
20	35	A	Data is source for reports.

20	36	A	Data is source for reports.
20	37	W	Data possibly source for reports.
20	41	A	Data possibly source for reports.
20	58	A	Chart data used in checking.
20	62	W	Type of supplementary data.
20	66	W	Type of supplementary data.
20	68	W	Requires certain supplementary Chart data.
20	72	A	Descriptors may need to be used for supplementary Chart data.
20	73	W	Descriptors may need to refer to supplementary Chart data.
21	23	W	Would need to transfer data at year end.
21	29	S	Requires current budget data.
21	30	S	Used in monitoring reports.
21	31	S	Used in monitoring reports.
21	32	S	Used in monitoring reports.
21	33	A	Used in monitoring reports.
21	35	W	Portions of data may be used as input to DM.
21	38	A	Need budget data to do function.
21	39	A	Choices may include CFY budget data.
21	40	S	Variations may require certain CFY budget data.
21	60	A	Proposed revire often requires examination of CFY budget data.
21	62	A	Part of CFY budget data.
22	29	A	Future budget data submitted in prorated form subject to change.

22	32	S	Data needed for reports.
22	35	A	Data needed by DM.
22	36	A	Requests for future budget data.
22	41	A	May require future budget data.
22	60	A	Review of data maintained.
22	61	A	Review of data maintained.
22	62	W	S of F data must be maintained with future budget data.
22	63	A	Automatic changes will be applied to future budget data.
22	65	A	Commonality in how to treat data.
23	36	A	Needed for requests.
24	31	A	Needed for monitoring operating budget.
24	33	A	Source data for reports.
24	34	A	Source data for reports.
24	36	S	Heavily used data for ad hoc requests of information.
24	39	A	Optional data items must be available or derivable.
24	40	A	Required data for variations may include current acutal data.
24	41	A	May include current year actual data.
24	58	A	Needed for editing and checking of future budgets.
25	30	W	Actual data needed for funds application.
25	31	W	Needed for comparison to last year.
25	32	A	LFY Actual data is potential data source.

25	33	A	LFY Actual data is potential data source.
25	34	A	LFY Actual data is potential data source.
25	35	A	LFY Actual data is potential data source.
25	36	A	LFY Actual data is potential data source.
25	39	A	LFY Actual data is potential data source.
25	40	W	LFY Actual data is potential data source.
25	41	A	LFY Actual data is potential data source.
26	36	W	Ad hoc requests may need old budget data.
27	36	W	Ad hoc requests may need old budget data.
27	53	A	DM may need actual data for extrapolation/modelling.
28	38	A	Hiring data not now maintained.
28	56	W	Manual preparation may make use of some data.
28	57	S	On-line preparation will need data.
28	58	A	Certain preparation data needed for checking/editing.
28	59	W	Preparer might need to interact with limits information.
28	60	A	May need special data for review.
28	61	A	May need data for changes review.
29	30	S	Effective use of fund accounts depends on accurately prorated data.
29	31	A	Prorated data important for operations monitoring.
29	32	A	Prorating used in FB report generation.
29	40	W	Variation may involve modification to proration arrangements.

29	49	W	Changing proration may be done directly by managers via on-line access.
29	56	A	Budget prorated when proration established.
29	57	A	Budget prorated when proration established.
29	63	A	Automatic change to proration also.
30	36	A	Ad hoc requests for information regarding fund accounts important.
30	37	S	Fund reports should be addressed toward effective use.
30	62	W	Easy availability of S of F information should improve effectiveness of use.
30	69	A	Makes for more effective use.
30	70	W	Drafts related to effectiveness of use.
30	71	A	Fund draft checking can intercept ineffective use.
31	32	S	Periodic budget-versus-actual reports serve monitoring needs.
31	33	A	Periodic reports may serve monitoring capability.
31	34	A	Summary monitoring reports.
31	36	W	Ad hoc monitoring.
31	41	W	May need to develop new monitoring reports.
31	61	A	Changes impact monitoring function.
31	68	W	Special items may need special monitoring.
32	33	W	Common reporting issues.
32	34	W	Common reporting issues.
32	37	W	Common reporting issues.

32	40	A	Related reporting issue.
32	41	A	Related reporting issues.
32	61	W	Changes may be reviewed via reports.
32	64	W	Needed for certain report requirements.
33	34	A	Common data source.
33	36	A	Common data for typical queries and reports.
33	37	W	Common data source.
33	39	S	Common report modification issue.
33	40	A	Common data and reports.
33	41	S	Monthly analysis scheme common.
33	62	W	Sources of funding information may be in some reports.
34	36	S	May produce special-purpose report using ad hoc facility.
34	41	W	May develop new budget reports out of special-purpose reports.
34	42	A	May produce some special reports using report writer.
36	41	W	Ad hoc requirements may lead to new reports.
36	42	S	Most ad hoc requirements accommodated via report writer.
36	43	A	Users may wish to develop their own reports.
36	45	A	May use query facility to answer ad hoc questions.
36	48	S	Data control makes ad hoc query use more difficult.
36	72	A	New data item types make ad hoc requirements

easier to implement.

37 62 A Funding sources will be shown in funds report.

39 40 A May want general mechanisms for modification.

39 41 W Modifications may lead to new reports.

39 72 W New data item types can carry data regarding report content.

40 41 A Variations may lead to new reports.

40 65 W Budget report format may be used for research proposal reports.

41 65 A Research proposal information prime candidates for new reporting.

41 72 A Common data organization issue.

42 43 S Facility intended for users.

42 46 W Destination code in reports.

43 46 A Report directing aids must be available to all users and easy to use.

43 47 W Need to log id information regarding report writer users.

43 48 W Constrains use of report writer.

43 74 S Train use of report writer - make it easy to use and learn.

44 46 W Possibly need to dump menu-query output to terminals.

44 47 A Log query users.

44 48 A Control query access.

44 60 A Proposal review could use query facility.

44	61	A	Proposal review could use query facility.
44	71	A	Use query facility for funds drafts.
44	74	A	User training would be necessary.
45	46	W	May need to send ad hoc results to users terminals.
45	47	A	Log query users.
45	48	A	Control query access.
45	74	A	Need user training.
46	77	W	Can achieve faster distributino via remote printing of reports.
47	48	A	Need identity to determine permissable users.
47	49	A	Need identity to determine owner.
47	53	A	Activity logging would include database changes.
48	49	A	Common access control issue.
48	50	S	Common access control.
48	52	A	Encoding can be used to insure that only permissable users get access.
49	51	S	Need owner id concept to implement control.
49	52	W	Encoding can be used to insure that only permissable users can change items.
49	53	W	Validity of change attempts logged.
50	51	W	Common access issue.
53	55	S	Need log to restore.
53	61	A	Can locate changes via log stream.
53	63	W	Need to log automatic changes to EBs.
53	67	S	Log is important part of audit trail.

53	72	A	Need to log additions of new data elements.
54	55	S	Restore via backup.
54	67	W	Might want to perform control total checks prior to backup.
55	67	A	Restoration would have to meet audit checks.
56	57	W	Common prep. activities.
56	58	W	Data format, etc., common.
56	60	W	Entry of manual proposals must lead to Budget Office review.
56	74	W	Need documentation for manual entry.
57	58	A	Will want to chack on-line preparation.
57	60	W	Common on-line processing.
57	74	W	On-line activities for users must be easy to learn and teach.
58	59	S	Control limits key to automatic checking.
58	60	A	Budget Office review forms part of check.
58	62	A	Check sources as part of checking procedures.
58	66	W	Check that category codes correct.
58	75	A	Adds complexity to automatic checking funstion.
59	60	A	Review against controlling limits.
59	61	A	Review changes controlling limits.
59	62	A	Controlling limits may be tied to S of F.
59	63	W	Automatic incrementation in employee benefits requires secondary check.
59	65	W	Suspense file approach tied in with controlling limits.

59	68	W	There are limits on such items.
59	71	S	Commonality in performing checks.
59	75	A	Control limits must take this into account.
59	76	A	Relevant to checking overhead amounts.
60	61	A	Common review mechanisms.
60	62	S	Sources of funding important aspect of review.
60	65	A	OSP can use same mechanism to review research proposals.
60	66	W	Would have to check categories.
60	68	W	Checking overlap, although mainly manual.
60	71	A	Budget Office must be able to review these also - common facility possible.
61	62	A	Changes often incorporate new funding.
61	63	W	Automatic changes make change review more difficult to execute.
61	65	A	May need to review RP changes.
61	66	W	May need to review RP changes.
61	68	A	Changes to budgeted amounts of some non-recurring expenses may need to be reviewed.
61	71	A	Common review requirements - potential common facility.
62	65	W	S of F data related to research proposal preparation.
62	71	A	Need to check fund draft against account funded to.

63	67	A	Need to keep audit log of changes to employer benefits.
63	75	S	Automatic changes more difficult under this requirement.
64	74	A	Need to be able to train in all techniques.
65	66	A	Categorization information part of data base.
65	76	A	Overhead rates are important in manipulation of proposals.
67	68	A	Non-recurring expense transactions must be included in audit trail.
67	69	A	Fund drafts must be included in audit trail.
67	70	A	Fund drafts must be included in audit trail.
67	75	W	Non-standard employee benefits must be auditable.
67	76	W	Overhead recovery rates must be auditable.
68	71	W	Fund drafts for most non-recurring expenses must be chacked.
69	70	A	Common processing issue.
72	73	S	Application of new data item types.

Appendix F

REQUIREMENT SUBSETS DERIVED FROM THE BEST SYSTEM DECOMPOSITION.

*** SUBPROBLEM 1 ***

7. Data regarding special financial arrangements made by managers will be maintained.

28. Data required for budget proposal preparation and not available elsewhere will be maintained.

38. The system will have access to certain personnel hiring data.

56. Budget proposals can be prepared manually.

57. Budget proposals can be prepared on-line.

58. Budget proposals will be automatically checked and edited to the extent possible.

59. There will be controlling limits on amounts in proposed budgets and budget changes.

60. Budget proposals will be reviewed by the budget office and/or OSP.

61. Budget changes will be reviewed by the budget office and/or OSP.

62. Sources of funding for each account will be identified.

65. Research proposal information can be stored, updated, and accessed.

66. Research accounts and proposals will be categorized by type, discipline, and function.

68. Required aspects of non-recurring expenses will be supported.

71. Fund drafts can be checked and approved on-line by Budget Office.

76. Overhead recovery rate calculations will be supported.

*** SUBPROBLEM 2 ***

18. There will be a general comparison reporting capability.

19. Items exceeding prespecified bounds can be highlighted.

20. Chart of Accounts and associated supplementary data will be accessable by Budget System.

21. Current fiscal year budget data will be maintained.

22. Future Budget data will be maintained.

23. Last fiscal year Budget data will be maintained.

24. Current fiscal year Actual data will be maintained.

25. Last fiscal year Actual data will be maintained.

26. Historical Budget data will be maintained for up to 1 years.

29. Budgeted income and expense data will be prorated automatically on a month-by-month basis.

31. Monitoring of the operating budget will be supported.

32. Various Future Budget reports will be generated.

33. Periodic operating reports for each account will be generated.

34. Various special-purpose (non-periodic) reports will be generated.

36. Ad hoc requests for information will be supported.

39. Certain budget report data items can be optionally included or excluded from Monthly Analysis Report

as specified by the user.

40. Variations of standard Budget System reports will be developed as requested.

41. New budget reports will be developed as required.

42. There will be a simple report-writing facility.

*** SUBPROBLEM 3 ***

16. Budgeting and planning data can be accessed readily by other systems.

43. Users can develop their own special reports using the report writing facility.

44. There will be an on-line menu-oriented query facility.

45. There will be an on-line ad hoc query facility.

46. Reports generated on-line can be directed to the system printer or to users' printer/terminal.

47. Identity and activity of users will be logged.

48. Data items can be accessed only by permissable users.

49. Data items can be changed only by their owner.

50. There will be a set of permissable users for each data item.

51. Each data item will have a unique owner.

52. Data items can be encoded for security.

64. All currently used budgeting techniques will be supported.

74. Formal training in the use of the system will be provided to users.

*** SUBPROBLEM 4 ***

15. Reports will be physically easy to handle.

77. Standard periodic reports will be produced and distributed to users as quickly as possible.

*** SUBPROBLEM 5 ***

9. Personnel budgets can be developed in EFT.

10. There will be a facility for converting salary/wage information between dollars and EFT.

13. Manpower can be reported in alternative units.

*** SUBPROBLEM 6 ***

53. There will be a log of all database changes.

54. There will be a file backup facility.

55. The database's integrity can be restored using backup files and change log if necessary.

67. There will be documented audit trails for determining system discrepancies.

69. Fund drafts can be performed on-line.

70. Fund drafts can be performed in batch mode.

*** SUBPROBLEM 7 ***

11. Certain objects may be logically related to groups of other objects.

12. A particular object may belong to multiple object groups.

14. There will be special object codes available for use by each department.

*** SUBPROBLEM 8 ***

5. Short-term and long-term planning data will be provided by Senior Managers.

6. Planning data will be provided in a standardized format.

27. Historical Actual data will be maintained for up to 1 years.

35. The data necessary for use by the Dynamic Model will be generated.

*** SUBPROBLEM 9 ***

8. Personnel budgets can be developed in dollars.

63. Budgeted employee benefits will be changed automatically following changes in budgeted salary and wage amounts or EB rates.

75. Non-standard employee benefit calculations will be supported.

*** SUBPROBLEM 10 ***

1. Fund accounts will be categorized by fund purposes.

2. Fund accounts can be categorized by principal type.

3. Fund accounts can be categorized by income type.

4. Each fund account will be described via abbreviated text description.

17. The budget system can access directly data in other systems' files.

30. Information to facilitate the effective use of fund accounts will be available.

37. Various funds reports will be generated.

*** SUBPROBLEM 11 ***

72. Additional data item types can be added to accounts or objects within accounts.

73. New data items can include or refer to supplementary data needed by users.

Appendix G

INTERDEPENDENCIES BETWEEN REQUIREMENT SUBSETS IN BEST DECOMPOSITION.

CLUSTER PAIR	INTERDEPENDENT NODES		
1, 2	38, 21,A	56, 29,A	58, 20,A
	58, 24,A	60, 21,A	60, 22,A
	61, 22,A	61, 31,A	61, 32,W
	62, 20,W	62, 21,A	62, 22,W
	62, 29,A	62, 33,W	65, 22,A
	65, 40,W	65, 41,A	66, 20,W
	68, 20,W	68, 31,W	
1, 3	56, 74,W	57, 74,W	60, 44,A
	61, 44,A	71, 44,A	
1, 4	** NONE **		
1, 5	28, 10,A	38, 9,W	38, 10,W
	59, 9,W		
1, 6	61, 53,A	68, 67,A	76, 67,W
1, 7	** NONE **		
1, 8	** NONE **		
1, 9	58, 75,A	59, 63,W	59, 75,A
	61, 63,W		
1, 10	7, 3,A	7, 30,A	7, 37,W
	58, 1,A	60, 1,A	62, 30,W
	62, 37,A	71, 1,W	71, 17,W
	71, 30,A		
1, 11	** NONE **		
2, 3	29, 48,W	32, 64,W	36, 43,A
	36, 45,A	36, 48,S	42, 43,S
	42, 46,W		
2, 4	** NONE **		
2, 5	29, 9,A	33, 9,A	

2, 6	** NONE **		
2, 7	34, 11,A	34, 12,S	
2, 8	18, 27,W	20, 35,A	21, 35,W
	22, 5,S	22, 6,W	22, 35,A
	25, 35,A	34, 5,A	34, 6,W
	36, 27,W		
2, 9	22, 63,A	29, 8,A	
2, 10	19, 3,A	20, 1,A	20, 2,A
	20, 3,A	20, 17,S	20, 37,W
	21, 30,S	25, 30,W	29, 30,S
	32, 37,W	33, 37,W	36, 1,W
	36, 2,W	36, 3,A	36, 4,W
	36, 30,A		
2, 11	20, 72,A	20, 73,W	36, 72,A
	39, 72,W	41, 72,A	
3, 4	46, 77,W		
3, 5	** NONE **		
3, 6	47, 53,A	49, 53,W	
3, 7	** NONE **		
3, 8	** NONE **		
3, 9	** NONE **		
3, 10	** NONE **		
3, 11	** NONE **		
4, 5	** NONE **		
4, 6	** NONE **		
4, 7	** NONE **		
4, 8	** NONE **		
4, 9	** NONE **		
4, 10	** NONE **		
4, 11	** NONE **		
5, 6	** NONE **		
5, 7	** NONE **		
5, 8	** NONE **		

5, 9	10, 8,S	13, 8,A	
5, 10	** NONE **		
5, 11	** NONE **		
6, 7	** NONE **		
6, 8	** NONE **		
6, 9	53, 63,W	67, 63,A	67, 75,W
6, 10	69, 17,W	69, 30,A	70, 30,W
6, 11	53, 72,A		
7, 8	11, 35,A		
7, 9	** NONE **		
7, 10	** NONE **		
7, 11	** NONE **		
8, 9	** NONE **		
8, 10	** NONE **		
8, 11	** NONE **		
9, 10	** NONE **		
9, 11	** NONE **		
10, 11	1, 72,S		