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GUIDELINE FOR CHOOSING A DATA MANAGEMENT APPROACH

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CATEGORY: DATA MANAGEMENT APPLICATIONS

FIPS PUB 110

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Foreword

The Federal Information Processing Standards Publication Series of the National Bureau of Standards (NBS) is the official publication relating to standards and guidelines adopted and promulgated under the provisions of Public Law 89-306 (Brooks Act) and under Part 6 of Title 15, Code of Federal Regulations. These legislative and executive mandates have given the Secretary of Commerce important responsibilities for improving the utilization and management of computers and automatic data processing in the Federal Government. To carry out the Secretary's responsibilities, NBS, through its Institute for Computer Sciences and Technology, provides leadership, technical guidance, and coordination of Government efforts in the development of guidelines and standards in these areas.

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Abstract

This Guideline assists the Federal data processing manager in the identification and selection of a data management approach appropriate to organizational requirements. In this Guideline is a framework for comparing and selecting alternative data management approaches. The emphasis is on pragmatic guidance that captures the principal, relevant decision factors.

Key words: data management system; data processing management; database management system; DBMS; DMS; Federal Information Processing Standards Publication; file management.

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ANNOUNCING THE

GUIDELINE FOR CHOOSING A DATA MANAGEMENT APPROACH

Federal Information Processing Standards Publications are issued by the National Bureau of Standards pursuant to the Federal Property and Administrative Services Act of 1949, as amended, Public Law 89-306 (79 Stat. 1127), and as implemented by Executive Order 11717 (38 FR 12315, dated May 11, 1973), and Part 6 of Title 15 Code of Federal Regulations (CFR).

Name of Guideline: Guideline for Choosing a Data Management Approach.

Category of Guideline: Software, Data Management Applications.

Explanation: This Guideline assists Federal data processing managers to identify and select a data management approach appropriate for their organizational environments and application requirements.

Approving Authority: U.S. Department of Commerce, National Bureau of Standards (Institute for Computer Sciences and Technology).

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Cross Index:

a. Federal Information Processing Standards Publication (FIPS PUB) 21-1, *COBOL*.

b. Federal Information Processing Standards Publication (FIPS PUB) 31, *Guidelines for ADP Physical Security and Risk Management*.

c. Federal Information Processing Standards Publication (FIPS PUB) 38, *Guidelines for Documentation of Computer Programs and Automated Data Systems*.

d. Federal Information Processing Standards Publication (FIPS PUB) 41, *Computer Security Guidelines for Implementing the Privacy Act of 1974*.

e. Federal Information Processing Standards Publication (FIPS PUB) 64, *Guidelines for Documentation of Computer Programs and Automated Data Systems for the Initiation Phase*.

f. Federal Information Processing Standards Publication (FIPS PUB) 68, *Minimal BASIC*.

g. Federal Information Processing Standards Publication (FIPS PUB) 69, *FORTRAN*.

h. Federal Information Processing Standards Publication (FIPS PUB) 76, *Guideline for Planning and Using a Data Dictionary System*.

i. Federal Information Processing Standards Publication (FIPS PUB) 77, *Guideline for Planning and Management of Database Applications*.

j. Federal Information Processing Standards Publication (FIPS PUB) 88, *Guideline on Integrity Assurance and Control in Database Administration*.

k. Federal Information Processing Standards Publication (FIPS PUB) 99, *Guideline: A Framework for the Evaluation and Comparison of Software Development Tools*.

l. Federal Information Processing Standards Publication (FIPS PUB) 101, *Guideline for Lifecycle Validation, Verification, and Testing of Computer Software*.

Applicability: This Guideline is intended as a basic reference for Federal data processing managers who are responsible for the planning, evaluation, and selection of agency data management strategies and tools.

Implementation: This Guideline should be consulted when Federal agencies are planning for new data management applications, or a conversion or redesign of old data management applications, or acquisition of new data management tools.

Specifications: Federal Information Processing Standards Publication 110 (FIPS PUB 110), *Guideline for Choosing a Data Management Approach* (affixed).

Qualifications: This Guideline represents recommended good practices for identifying and selecting a data management approach appropriate for most typical Federal Government applications. In applying this Guideline, it is important to bear in mind that data management technology is rapidly evolving to take advantage of new hardware and software capabilities, and that each Federal agency must take into consideration its own specific circumstances when applying or referencing this publication.

Where to Obtain Copies of the Guideline: Copies of this publication are for sale by the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. When ordering, refer to Federal Information Processing Standards Publication 110 (FIPSPUB110), and title. When microfiche is desired, this should be specified. Payment may be made by check, money order, or NTIS deposit account.

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Specifications for

GUIDELINE FOR CHOOSING A DATA MANAGEMENT APPROACH

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1. INTRODUCTION

1.1 Background

The increasing demand for new or improved computer applications on Federal data processing (DP) facilities has created a growing problem for facilities managers. Staff and budget constraints limit the ability of DP managers to respond to this demand. Antiquated or inadequately designed systems have created severe maintenance and performance problems, leaving little time to develop new applications or to improve existing applications. One strategy for dealing with these problems is to improve the DP facility's productivity through selection and utilization of the most appropriate data management approach for a given application. A data management approach in this Guideline means a particular strategy and its accompanying tools to solve application problems.

One can view the various data management approaches as a spectrum ranging from traditional application system (file oriented, usually in COBOL) to database management system (an integrated, shared data resource utilizing data dictionaries, query languages, report writers, telecommunications software, and other features). There are various commercial packages or groupings of packages that fit somewhere along that spectrum. However, this Guideline describes and analyzes these three major data management approaches:

- Traditional Application System (file environment)
- Database Management System (DBMS), and
- Data Management System (DMS) (file environment plus).

This Guideline focuses upon these three approaches because they are representative of the three major strategies that are now being used for data management.

Each data management approach is supported by a large number of commercial software packages. For the Traditional Application System approach, virtually all large scale computers, minicomputers, and most microcomputers have COBOL and other high level language compilers. The DBMS and DMS approaches represent hundreds of individual application packages. DBMS's are commonly found on mainframe and minicomputers. DMS's are available on all sizes of computers, and are currently very popular on microcomputers.

One of the most serious and costly problems in data management is the lack of correspondence between user requirements and appropriate data management approaches. The most costly aspect is not the purchase price of a particular software tool or tools, but the investment in application programs that may not meet user requirements. By providing a framework for the data processing manager to analyze various data management approaches, this Guideline provides assistance in narrowing the number of data management software tools that must be reviewed in choosing the appropriate tool or tools to meet organizational requirements.

This Guideline describes and analyzes critical factors such as the organizational structure, hardware, software, people, dollars, and other constraints that limit the success or increase the odds of failure of a given data management approach. Hopefully, this Guideline will assist Federal Government managers to assess their individual environments and to determine which of the data management approaches is most likely to be successful.

1.2 Traditional Application System

The Traditional Application System data management approach involves the development of specially designed application software programs. These software programs provide all the needed application functions, and are usually written in COBOL or another high level programming language. Data records having simple and common formats are combined into distinct files. The programming staff develops each application separately, working out program logic and file designs that seem convenient and effective for the specific required processing [NBS-80a]. The programming staff must be aware of the appropriate file access methods, and must support relationships between files by special programming procedures. In most cases, processing with the Traditional Application System approach relies heavily on batch mode.

1.3 Database Management Systems

The Database Management System (DBMS) approach, as the name implies, utilizes a commercially available DBMS. A DBMS is a software system allowing multiple, independent users concurrent access to a shared database. A database consists of an interrelated set of data stored together with controlled redundancy to serve one or more applications. The DBMS provides a controlled approach for adding new data, and modifying and retrieving existing data within a database. The DBMS approach provides a degree of data independence in that the data can be accessed logically without knowing any special physical access method procedure supporting the data access. Additional definitions of a DBMS can be found in [FIPS-79] and [MART-83].

Today DBMS vendors have provided a complete set of integrated tools along with the basic DBMS package. These tools include data dictionary, teleprocessing monitor, query facility, report writer, application development facility, and special-purpose application packages built upon the DBMS. Integrated tools can make the DBMS environment much easier to use. The provision of integrated tools is still relatively new.

In the middle 1970s users had a choice of two major categories of DBMS's: data processing oriented DBMS's and end-user oriented DBMS's. The data processing oriented DBMS, exemplified in the CODASYL DBMS specifications [CODA-81], did not provide query facilities and required a fair amount of expert knowledge about the DBMS package. The data processing oriented DBMS provided rich data structuring capabilities, and performance could be tuned by choosing access methods and physical storage strategies most appropriate for the application.

End-user oriented DBMS's, characterized by an inverted file access technique [TSIC-77], were, in the 1970s, and are today very good at extracting a small amount of data (usually much less than 5%) from a large database and quickly presenting the results to the user. End-user oriented DBMS's users had a query/update language to obtain the information of interest and produce reports. Although data updating could be handled with the query/update language, updating was done typically with a batch program that performed the updating overnight for processing efficiency. End-user oriented DBMS's also provided some ability to add or delete data fields without unloading and reloading the existing database.

From the middle 1970s until now DBMS vendors have maintained the existing functionality of their products while adding additional capabilities to their DBMS. Data processing oriented DBMS vendors have added their own query/update facility which was a large step in improving end-user access to the data in the DBMS.

Within the last few years a new type of DBMS, a relational DBMS [DATE-75], has become available in the marketplace and offers more characteristics of an end-user oriented DBMS than a data processing oriented DBMS. However, a relational DBMS also provides a dynamic structuring capability that provides flexible ways of integrating together data from various sources. Both data processing oriented and end-user oriented DBMS vendors have added some of the tools described above.

Today, although DBMS packages may appear to have externally similar capabilities, end-user oriented DBMS are still best in data retrieval, and data processing oriented DBMS are best in data structuring, data sharing, and performance tuning capabilities. If the user decides that the DBMS approach is the best approach for a given application, the user can then concentrate upon selecting the most appropriate DBMS package and appropriate tools for the DBMS approach.

1.4 Data Management Systems

A Data Management System (DMS) approach can be characterized as a compromise between the Traditional Application System and the DBMS approaches. There really are many different approaches in the spectrum between these two approaches. The DMS approach described here occupies a portion of that spectrum, and has its roots in the Traditional Application System approach because it relies on a file approach [DATA-84]. A DMS approach generally provides fewer additional tools than the DBMS approach. One major difference between DBMS and DMS approaches is that the DBMS approach supports integrated data sharing without redundancy for multiple applications. The DMS approach may not provide for integrated data sharing or may provide less data sharing capability than a DBMS. The DMS approach is primarily intended for a single application.

It is not unusual for a user to choose a DBMS and not utilize its data sharing capabilities. Using a DBMS in this manner is similiar to using a DMS approach.

Some DMS's come combined with various tools. Other DMS approaches require the user to mix and match tools to accomplish the desired functions.

There are many DMS-type packages available for users on microcomputers. Vendors of these packages prefer to call them "database management systems" or "data managers."

1.5 Overview

Figure 1-1 shows the framework for assessing data management approaches that will be developed in this Guideline. The framework will be described in chapter 5, and individual portions of the framework will be described as noted in figure 1-1.

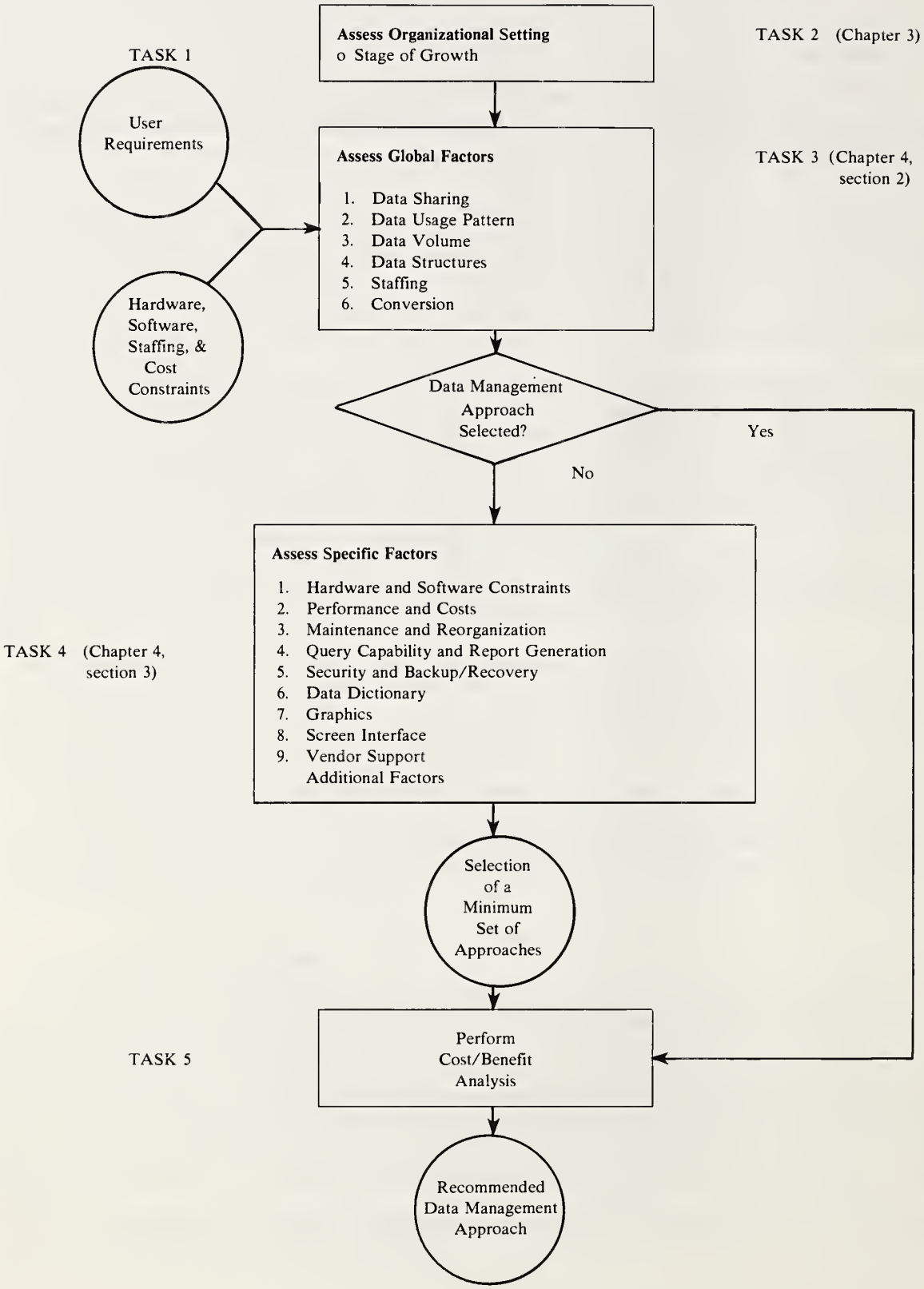

Figure 1-1. *Framework for assessing data management approaches*

Chapter 2 addresses the technological and managerial considerations associated with effective data management approaches. Chapter 3 introduces the organizational context in which most Federal data management system decisions are made, and compares that context to the three data management approaches. Chapter 4 identifies and defines key factors that should be considered during the evaluation process, and provides guidance on their use. Finally, chapter 5 provides a framework utilizing the organizational context and key factors for assessing and selecting data management alternatives. References and additional readings follow chapter 6.

An evaluation of commercial packages available for the selected data management approach must also be done. Detailed technical evaluation of commercial packages is beyond the scope of this Guideline. However, there are many similarities in the process of assessing a data management approach and in evaluating commercial data management packages. For large applications, benchmarking may be necessary to ensure that a particular commercial package will meet size or performance requirements. References useful in performing a technical evaluation are [COHE-73], [BROW-82], [FRAN-84], [LETM-84], [GALL-84a], and [BENI-84].

2. THE REQUIREMENTS FOR DATA MANAGEMENT APPROACHES

2.1 Requirements Estimate

Over the next 5 years a large number of Federal DP managers must make comparison and selection decisions concerning data management approaches. One way to size that expectation is to estimate the number of DMS's and DBMS's that are projected to be in place in the 1985–1990 timeframe, and to infer that each of these applications requires comparison and selection decisions.

By 1981, the Federal Government had over 15,000 computer central processing units (CPU's) installed, approximately 50% of which were less than 5 years old [GRAY-81]. Although exact data are not available, NBS has estimated that a majority of these existing Federal computer systems could support a DBMS package, if such packages were available [DRAP-81]. Notwithstanding that potential, there were only about 3,700 DBMS's in use in the Federal Government at that time [GAO-79]. Currently, it is believed that at least 60% of the computers installed support at least one file management, report writer, or other general data management package.

Over the 1985–1990 timeframe the Federal Government is projected to have over 40,000 computers. By 1985 at least 28% of the CPU's installed will have some type of DBMS [GRAY-81]. Most Federal computers in the 1985–1990 timeframe will have some type of file or data management capability [LITT-81]. These projections imply that by 1990 there could be over 30,000 DMS's and DBMS's within the Federal Government; roughly a 10-fold increase over the 1980/81 estimate.

Given the potential that over 30,000 new data management related packages will be selected and implemented in Federal DP facilities by 1990, responsible DP managers will need all the assistance possible in making their selection decisions as cost effective as possible. Even if these data management facilities are "included" in a hardware buy, the decision to use one capability versus another can have enormous cost/benefit implications.

2.2 New Technologies Which Could Affect the Estimate

Three recent computer technology changes that could significantly impact the above estimate of data management systems installed by Federal DP facilities are microcomputers, computer networks, and database machines. Their cumulative effect is expected to increase the need for and usage of data management systems as discussed below.

During the 1970's there was a lack of data management software on small (micro) computer systems, primarily because of technological limitations which existed at that time. Recent improvement in memory capacity, storage size, processor speed and data transfer rates have removed these technological barriers. Many small computers now allow for effective implementation of data management software [BRON-83].

Microcomputer, and to some extent minicomputer, data management technology is still at an early stage of what is likely to be a long evolution [BRON-83]. However, based on lessons learned during the implementation of data management software on large mainframe systems, it is expected that micro data management software will be enhanced considerably during the next 5 years. In addition, several DBMS vendors are currently developing compatible DBMS software modules capable of operating on both small (mini-micro) computers as well as large mainframes [BRON-83]. Because of the present early stage of data management

evolution on microcomputers and minicomputers, performance continues to be an important consideration. [BENI-84] considers performance factors in the selection of data management software on microcomputers, minicomputers, and database machines.

By 1990, the extremely rapid growth in the numbers of microcomputers available and in-place in the Federal Government, along with the growing data management capability for these systems can easily lead to even larger numbers of DMS's and DBMS's than estimated above.

Contemporary microcomputer data management software may not satisfy the processing requirements of many Federal agencies, but the proliferation of networks and distributed processing indicates that data management software will be essential to the future of microcomputer applications in the Federal Government.

It has been estimated that there were 1,370 Federal computer networks in 1980 which required some form of high level network protocol [FIOR-81]. In addition, estimates indicate that by 1989 approximately 35% of the computer systems in the Federal Government will be tied into one or more networks [FIOR-81]. If estimates of approximately 40,000 computers during this timeframe hold, there could be easily over 13,000 computers in networks within the Federal Government by 1990. The current projected uses of these networks and uses of distributed data processing implies that most, if not all, of the computers involved in these networks could require a data management capability of some type. This requirement could also increase the projected number of data management decisions.

Another technology change which could have an impact on the number of DMS's and DBMS's in use by 1990 is the current development of database hardware. For many years, researchers have been investigating the possibility of a database machine, but until the last few years no such machine had actually been implemented. Commercial implementations have been few, but if such machines prove cost-effective it is possible that a number could be in use in the Federal Government by 1990. If this occurs, there will probably be a corresponding fewer number of data management systems procured for "traditional" computer hardware as they are replaced or augmented with database hardware.

In summary, the projected rapid growth in microcomputer applications is likely to increase the demand for DMS's or DBMS's installed in the Federal Government by 1990. Expected increases in the number of data management systems due to the growth of Federal DP networks will most likely be offset by potential decreases due to high level network DBMS protocols. Overall, the estimate that over 30,000 new data management systems will be installed in the Federal Government by 1990 is believed to be a reasonable, conservative expectation.

3. DATA MANAGEMENT DECISION CONTEXTS

3.1 Organizational Setting

There are many contexts in which the Federal DP manager makes decisions about the evaluation and selection of data management alternatives. Issues affecting these decisions include the stage of development of the data processing organization, the current and planned needs of the user community, existing application processing systems, available hardware, and the impact on future data processing growth within the organization.

Each of these organizational issues can affect the type and appropriateness of solutions to meet existing and expected data processing requirements. Before discussing the data management evaluation and selection process, it is useful to first describe the situations in which the process occurs in terms of the different stages of growth that data processing shops typically experience.

The idea that most data processing shops experience similar stages of growth was first presented by Nolan in 1973 [NOLA-73]. His initial paradigm of four stages of growth of a data processing organization has been expanded to reflect six discrete stages of growth [NOLA-79]. Briefly, the six stages are:

Stage I—Initiation, begins when the first computer appears in an organization. Usually the group responsible for justifying the computer has control over it and over the applications developed for it.

Stage II—Contagion, occurs where high level management accepts the computer as a positive good for the organization. During this stage, more and more users have computer programs developed.

Stage III—Control, occurs when the processing volume on the computer requires that management actively enforce formal information system planning and control. Existing applications are reviewed and restructured to make better use of the computer resource. Often during this stage there is a tendency to centralize processing and control of applications.

Stage IV—Integration, involves a rethinking of the role of the computer resource within the organization. This is usually manifested by an upswing in user involvement and implies the acquisition/use of tools which are more user-oriented. This often results in retrofitting existing user applications utilizing DBMS technology.

Stage V—Data Administration, involves the establishment of a data control function with an integration of applications and shared data.

Stage VI—Maturity, occurs where application software integration mirrors information flows, and the user community accepts greater responsibility for the design and operation of applications.

These stages of growth correspond roughly with the four types or classes of data environment presented by Martin [MART-83]. Briefly, the characteristics of Martin's classes of Data Environment are:

Class I—Environment-Files, where separate files of data are used for most applications. A large proliferation of files occurs with high levels of redundancy. Seemingly trivial changes can trigger subsequent, often unanticipated, ripple effects throughout the data files.

Class II—Environment-Application Data Bases, where data management or data base management systems are used without sharing of data. Separate data bases are designed for separate applications.

Class III—Environment-Subject Data Bases, where data bases are created which are largely independent of specific applications. Data are defined and stored independently of the function for which they are used.

Class IV—Environment-Information Systems, where data bases are organized for searching and fast information retrieval rather than for high-volume production runs. May coexist with a Class III Environment.

Figure 3-1 shows how these two representations of growth in the data processing environment and the FIPS data management approaches might compare. Most Federal DP facilities and their parent agencies have reached at least Nolan's third stage of growth and Martin's Class II of data environment. This implies that these organizations should be seriously involved in the evaluation, selection and use of DMS's and DBMS's. As a DP organization evolves into the later stages of growth, more and more emphasis will be placed on effective database management.

While the stage of an organization's development may affect the data management solution available to the Federal DP manager, other issues such as user needs and attitudes and available computer hardware are also pertinent.

User needs can heavily influence the set of appropriate data management alternatives available to the Federal DP manager. If the user community for a particular DP facility is generally satisfied with the current DP support, and has no plans to implement any new large application, the DP manager's options may be very different from those alternatives when the user community is dissatisfied with the current level of DP support, or has a need for one or more new large application systems.

Available computer hardware is another important issue that affects the options available to a DP manager. For example, if the existing hardware has sufficient capacity available to support a new DMS or DBMS system, the selection process will be different from the process for selecting new computer hardware and data management software.

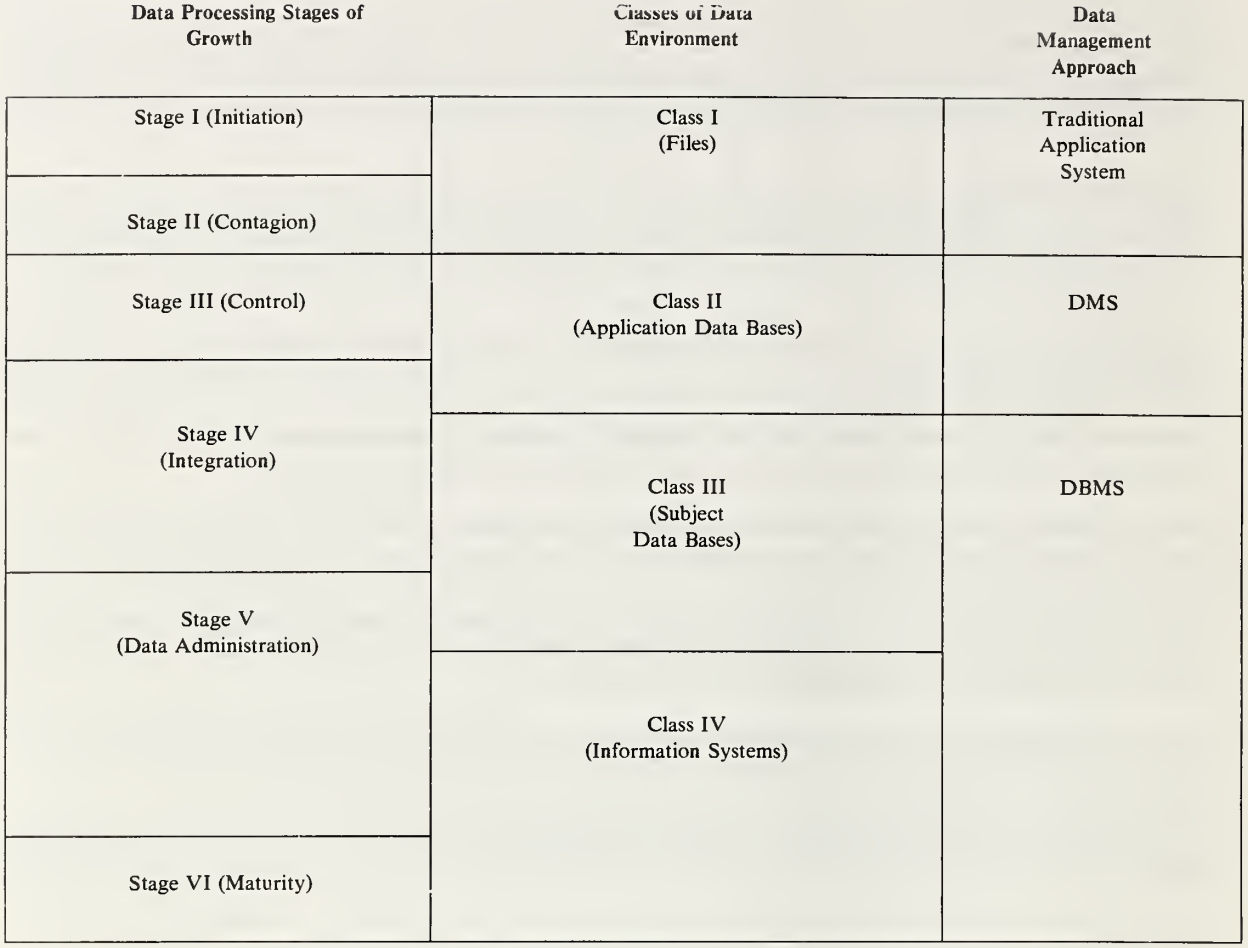

Figure 3-1. *Comparison of the two models of data processing organization growth with the three FIPS data management approaches.*

4. IMPORTANT FACTORS IN SELECTING A DATA MANAGEMENT APPROACH

4.1 General

The previous chapter discussed the basic data management decision contexts in which the Federal DP manager makes decisions about the evaluation and selection of a data management approach. That chapter provides guidance on the likelihood of success of a data management approach given the organizational setting.

This chapter provides guidance in utilizing the results of the requirements analysis performed in an organization to select an optimal data management approach. There are certain global and specific key factors described in this chapter that the Federal DP manager should assess in the selection process. The importance of any one key factor depends upon the results of the organizational user requirements analysis.

Federal DP manager's objective in the selection process should be to reduce the number of data management approaches under consideration to one. (However, under some circumstances more than one approach can provide reasonable solutions to organizational needs.) The specific packages corresponding to the selected data management approach(es) will be analyzed later in a detailed technical evaluation including benchmarking, if appropriate, and a cost/benefit analysis.

The general philosophy that should be used in selecting among data management approaches is to find the best match between user requirements and available software capabilities. Capturing user requirements is a vital part of the selection process, because it documents needed functionality and provides a base to compare data management approaches. References on requirements analysis techniques can be found in [ORR-82] and [COHE-81].

4.2 Global Factors for Identifying a Data Management Approach

The following global factors can be used by Federal DP managers to identify which data management approach or approaches may best meet the organization's needs. These factors are global because they are generic considerations that are relevant to all DP facilities. Each factor is described and analyzed solely from the viewpoint of that factor. In most cases, the Federal DP manager must review these global factors and determine how the needed capabilities can be provided at the lowest overall costs. In some cases noted below, a particular data management approach may not be able to provide the needed functions at any cost. How important a particular factor is to an organization must be determined as a result of the organization's user requirements analysis.

4.2.1 Data Sharing

When multiple programs need to have access to the same data concurrently, data sharing is necessary. The Traditional Application System approach to data sharing involves duplication of the shared data in files. It is not unusual for each program to utilize different subsets of a file or various combinations of data from several files. For processing efficiency the data is duplicated. However, conflicts arise from this duplication when the same data contains different values in different files. This can occur during data updates when all duplicated copies must be immediately changed. If for some reason a copy is not updated, or access requests are made during the update process, then conflicting data values can exist in the database. These conflicts must be resolved at some cost in machine time and manpower. Using a Traditional Application System approach to data sharing is difficult because the mechanisms that would manage the sharing of data without redundancy are not available.

A DBMS approach provides a mechanism for managing data sharing without data redundancy by providing each user with a view of the centralized data resource appropriate for the application program. A DBMS approach also allows data access and updates concurrently to all users.

Since a DMS approach utilizes files, its capabilities in data sharing are similar to the Traditional Application System approach. However, some DMS's can provide some assistance in managing data sharing, but not to the degree that a DBMS approach provides.

Data Sharing Environment

The Traditional Application System approach is most effective under these circumstances:

- Applications use the same files and do not require various combinations or subsets of existing files.
- Users are not concurrently updating their data files.

The DBMS approach is most effective under these circumstances:

- Applications use various combinations and subsets of the organization's data resource.
- Simultaneous updating of data files is required.

The DMS approach is most effective under these circumstances:

- Applications use files and require some combinations or subsets of existing files.
- Users are not concurrently updating their data files.

4.2.2 Data Usage Pattern

Information concerning how the organization uses its data resources is gathered in the user requirements analysis. The results of the user requirements analysis are used in selecting the most appropriate data management approach.

The data usage pattern includes modes of use (batch or interactive), access time (amount of waiting time permitted to receive a report or the results of a query), and percentage of updates versus percentage of retrievals.

When reports or queries are known in advance, a very efficient program can be written with the Traditional Application System approach to accomplish the desired functions. Also, when the reports or queries are extremely unusual and known in advance, the Traditional Application System approach is usually a good choice. Under these circumstances, the additional capabilities that a DMS or DBMS approach can provide, may not be worth the additional computer resource costs. When the reports or queries are not known in advance, the additional capabilites of a DMS or DBMS (query and report writing) may become very cost effective in providing the report or results of a query in a timely manner.

The Traditional Application System approach tends to provide poor interactive response because of a lack of a query capability and lack of a built-in teleprocessing interface program. DMS and DBMS approaches provide query capabilities and the DBMS approach provides for teleprocessing.

Data Usage Pattern Environment

The Traditional Application System approach is most effective under these circumstances:

- Requests for information or reports are generally known in advance.
- Data processing operations are predominately in a batch mode.
- Data processing access time is not critical (can be accomplished in days or hours rather than minutes or seconds).

The DBMS and DMS approaches are most effective under these circumstances:

- Requests for information or reports are not generally known in advance.
- Data processing operations are predominately in an interactive mode.
- Data processing access time is critical (must be accomplished in seconds or minutes rather than hours or days).
- The majority of data accesses are retrieval requests as opposed to update requests.

4.2.3 Data Volume

All systems have limits concerning the amount of data they can contain. Generalized software system approaches like DBMS and DMS require more data storage than Traditional Application Systems to support the additional capabilities that they possess. Many extremely large application data files may not fit under either a DBMS or a DMS approach. This is true because the limited data storage areas supporting the DBMS or DMS approaches may not be large enough and cannot be expanded to do the job. When an extremely large data file will not run at all with a DMS or DBMS, then the Traditional Application System approach must be used.

In some cases more than one data management approach would work, for example with medium data files. The DP manager can then determine which one particular data management approach would use the least computer resources and manpower for a particular set of requirements.

Data Volume Environment

The Traditional Application System approach is most effective under these circumstances:

- Extremely large application data files are needed, and no other data management approach can be used due to system limitations.
- Small or medium data files are needed.

The DBMS approach is most effective under these circumstances:

- Medium to large data files are needed.

The DMS approach is most effective under these circumstances:

- Small or medium data files are needed.

4.2.4 Data Structures

Data structures refer to the type of structuring capabilities within a record and among different data records. The Traditional Application System approach supports simple and complex data structures within a record. DBMS approach supports simple and complex data structures within a record as well as static hierarchic or network structures among records. The DBMS approach is also very good at dynamically creating relationships among records such as joining and subsetting different record types. The DMS approach generally provides a restricted subset of the DBMS appproach for structuring within a record and between records due to resource limitations.

Data Structures Environment

The Traditional Application System approach is most effective under these circumstances:

- The data files contain complex structures within a record.
- Query and report processing do not require the combination of separate data files.

The DBMS approach is most effective under these circumstances:

- Processing requirements need complex structuring capabilities among two or more record types to support queries and reports.

The DMS approach is most effective under these circumstances:

- Less structuring capabilities than the Traditional Application System approach are needed within a record.
- Less structuring capabilities than the DBMS approach are needed among records.

4.2.5 Staffing

Staffing refers to the experience and quantity of people needed to support a data management approach. For the Traditional Application System approach users communicate their needs to the professional programming staff who will develop a custom higher-level language program to perform the desired function. The professional programming staff needs operating system support personnel to perform its job. However, without an adequate supply of skilled programming professionals, the Traditional Application System approach is not feasible.

In the DBMS approach, users can participate to a greater degree if they so desire in developing application programs, queries, or reports via an English-like query or reporting facility. This type of environment places a different type of demand on the professional programming staff. Some skilled specialists in the DBMS package environment are needed who devote their time to developing strategies for dealing with the conflicting user requirements, and to training users in the English-like language. Depending upon the number of custom reports needed, the number of people in the professional programming staff could be reduced from the Traditional Application System approach. Without an adequate supply of DBMS specialists, the DBMS approach will not work.

The DMS approach is similar to the DBMS approach in that some skilled specialists in the DMS package are needed. The DMS approach is best suited to an environment where skilled data processing professionals

are scarce, and the organization is content with the reports and queries that are easily done by the DMS package. In this environment the number of data processing professionals can be reduced significantly because the application specialist users are capable of formulating their own queries and reports. Without an adequate supply of DMS specialists, the DMS approach will not work.

Staffing Environment

The Traditional Application System approach is most effective under these circumstances:

- An adequate supply of professional programmers is available.
- Skilled DBMS or DMS specialists are not available, or cannot be developed with an organization, or cannot be acquired via contract.

The DBMS approach is most effective under these circumstances:

- Skilled DBMS specialists are available, or
- Skilled DBMS specialists can be developed from the present professional staff, or
- Skilled DBMS specialists can be acquired via contract.
- Users are willing to formulate their own queries and reports via an English-like query and reporting capability.

The DMS approach is most effective under these circumstances:

- Skilled DMS specialists are available or can be acquired.
- The professional programming staff is very limited and application development and queries must be shifted to users.
- Users can be satisfied with reports in a general format rather than precisely specified.
- Users are willing to formulate their own queries and reports via an English-like query and reporting facility.

4.2.6 Conversion

Conversion can be defined as the process of transporting a computer system from one environment to a different environment while maintaining the functional requirements of the original system [COLL-80]. Using this definition of conversion, redesign and new development are not included within conversion.

Conversion can be difficult with any of the data management approaches. However, the conversion will be easier if the new data management approach is as similiar as possible to the existing data management approach.

Many migrations from the old system environment to the new system environment that are called conversions should more appropriately be called redesigns or new designs because functional requirements have changed. These changed requirements would be documented in the requirements analysis. When the requirements have changed, the existing data management approach may no longer be the best choice to ease the difficulty of system migration while still meeting the organization's requirements.

The Traditional Application System would be the most appropriate alternative if the existing environment is a Traditional Application System approach, the user is satisfied with the existing performance, and the requirements analysis shows no new major development efforts that would significantly change the existing design. If the requirements analysis shows that new major development efforts are needed, then the DMS and DBMS approaches should be considered.

If the existing environment utilizes a DBMS approach, a DBMS approach would ease conversion. If the existing environment utilizes a DMS approach and redesign is not required, then a DMS approach would ease conversion. If redesign is also needed, then a DBMS approach should also be considered along with the DMS approach for conversion. An NBS Special Publication describing various approaches to data conversion is [GALL-84b].

Conversion Environment

The Traditional Application System approach is most effective under these circumstances:

- The Traditional Application approach is presently being used successfully in an organization, and user requirements indicate no major redesign or new development is needed.

The DBMS approach is most effective under these circumstances:

- The DBMS approach is presently being used within an organization.
- The Traditional Application System or the DMS approach is being used within an organization and existing user requirements are not being met.
- The Traditional Application System or the DMS approach is being used within an organization and future user requirements indicate that major redesign or new development will be needed.

The DMS approach is most effective under these circumstances:

- The DMS approach is presently being used successfully in an organization, and user requirements indicate no major redesign or new development is needed.
- The Traditional Application System approach is being used within an organization and existing user requirements are not being met.
- The Traditional Application System or the DMS approach is being used within an organization and future user requirements indicate that major redesign or new development will be needed.

The above global factors provide an initial screening of the data management approach alternatives, and should provide a good insight into feasible data management alternative solutions. Figure 4-1 lists the global factors and indicates a typical, representative ranking of the data management alternatives in terms of those factors. Each global factor is viewed independently, and a determination of the relative importance of each factor must be made based upon the organization's user requirements analysis.

In two of the global factors, data volume and staffing, there are limitations which would prohibit the use of a data management approach when the data volume is too large for a generalized package, or when there is insufficient DBMS or DMS approach expertise to do the job. With the other global factors a judgment must be made of how to provide the needed capabilities at the lowest cost for computing and people resources.

GLOBAL FACTORS	Traditional Application System	DMS	DBMS
Data Sharing	Poor	Fair	Good
Data Usage Pattern			
Reports/Queries known in advance	Good	Fair	Fair
Reports/Queries not known in advance	Poor	Good	Good
Batch mode processing	Good	Fair	Fair
Interactive mode processing	Poor	Good	Good
Retrieval requests	Poor	Good	Good
Data Processing Access Time is critical	Poor	Fair	Good
Data Volume			
Extremely large data files	Fair	Poor	Fair
Medium to large data files	Fair	Fair	Good
Small or medium data files	Good	Good	Fair
Data Structures			
Complex Structuring within a record	Good	Fair	Good
Complex Structuring between records	Poor	Fair	Good
Staffing			
Skilled professional programmers available	Good	Fair	Fair
Skilled DBMS professionals available	Fair	Fair	Good
Skilled DMS professionals available	Fair	Good	Fair
Users willing to formulate own queries	Poor	Good	Good
Conversion			
Existing user requirements not being met	Poor	Fair	Good
Major redesign or new development is needed	Poor	Fair	Good

Figure 4-1. *Implications of global factors*

4.3 Specific Factors for Selecting a Data Management Approach

An analysis of the above global factors is usually sufficient to determine a suitable data management approach. However, analyzing the following specific key factors can provide significant confirmation of the results obtained based on a consideration of the global factors only. These specific factors describe constraints imposed by available capabilities in the marketplace.

Each specific factor is described and analyzed solely from the viewpoint of that factor. When there are conflicting indications as to the preferred data management approach, the Federal DP manager must weigh the relative importance of the factors and make a judgement based upon the data management approach that best satisfies the most important user requirements. Also, the cost/benefit analysis described as part of the framework for selecting a data management approach in chapter 5 can also provide assistance in choosing a data management approach when a clear choice cannot be made.

4.3.1 Hardware and Software Constraints

Hardware Constraints

Hardware constraints are limitations placed on the data management system approach by the current or proposed hardware and telecommunications facilities. These constraints include:

- Availability of the DMS or DBMS approach packages on the existing or anticipated hardware environment. Most packages are designed for the most commonly used computer equipment, thus there may be no DMS or DBMS packages available, making the Traditional Application System approach the only alternative.

- Sufficient memory and storage capacity available on the computer to support a DMS or DBMS approach package. Frequently, for microcomputers and heavily used systems there is not sufficient capacity available to support a DBMS, thus making the DMS or Traditional Application System better approaches.

- Existing or proposed telecommunications facilities able to support a large influx in the number of interactive users. If the existing or proposed telecommunications facilities are not sufficient, then the effectiveness of a DBMS can be limited, and one of the other approaches best suited.

Software Constraints

Software constraints are limitations placed on the selection process by the existing/proposed computer software. A major software constraint is whether or not the operating system is compatible with the data management approach. The Traditional Application System approach can always be made compatible by using the available programming language. On the other hand, DMS and DBMS packages must be carefully evaluated to determine whether or not they are compatible. Another area where software constraints are especially pertinent is when existing (developed or purchased) software packages must interface with the new data management approach. These interfaces are usually complex and difficult and must be carefully evaluated for each of the data management approaches being considered.

The American National Standards Committee on Database is developing two DBMS standards: a draft proposed American National Standard Network Database Language (NDL)[ANSC-84a], and a working draft of a Relational Database Language (SQL)[ANSC-84b]. Many software constraints would be lessened with DMS and DBMS standards. These specifications, when approved, will be the first American National Standards for a DBMS.

4.3.2 Performance and Costs

Performance

Performance indicates how responsive the system is to the user. It includes how long it takes for the system to respond to a query for data, and can be influenced by many things including the number of concurrent users on the system, the amount of data in the database, and the data organization. In most situations, a DBMS will provide better performance than a DMS or a Traditional Application System approach. This better performance is due to the ability of the DBMS to tune the performance of the system to the application by specifying optional access methods. This tuning is done independently of the logical structure of the database. In addition, most DBMS's provide tools for measuring performance which is normally lacking in the DMS and Traditional Application System approaches.

Costs

Costs can be broken down into recurring and non-recurring costs. Non-recurring costs for Traditional Application System development include costs for requirements analysis and design studies, and for developing the application software. Non-recurring costs for a DMS or DBMS approach include Traditional Application System approach non-recurring costs, plus costs for evaluating possible DMS's or DBMS's; for acquiring and installing the DMS or DBMS; data base preparation; training; travel; and, other personnel-related activities for procurement and installation of the package.

Recurring costs for the Traditional Application System approach include salaries and fringe benefits of staff supporting the system, and charges related to direct support services, such as, for data entry. Recurring costs for the DMS or DBMS approach include: the Traditional Application System approach recurring costs, as well as charges related to the rental, lease and maintenance of the DMS or DBMS; training of new staff members in the use of the DMS or DBMS; and, in the case of a DBMS the costs associated with continuing vendor assistance.

The recurring costs for salaries to support the DMS and DBMS approaches can be considerably less than those for the Traditional Application System approach. This can occur when additional requirements for unforeseen queries, reports, or new applications are added to an already developed application system. The recurring costs for salaries would be less because less manpower would be needed to provide the additional capabilities when compared to the Traditional Application System approach.

4.3.3 Maintenance and Reorganization

Maintenance

Maintenance involves the correction, modification or enhancement of existing software so that the software can continue to meet user requirements. If an organization has a shortage of professional programming staff available for program maintenance, the development of complex application software is probably not a feasible solution. In this situation, the use of either a DMS or DBMS is indicated, because applications developed using these approaches normally require less coding than if developed using the Traditional Application System approach. Since there is less code with which the maintenance programmer must become familiar, the time necessary to make modifications to a DMS or DBMS application is usually less than it would be for the Traditional Application System approach. However, a DMS or DBMS will require some additional support from DBMS or DMS specialists, who must maintain the DBMS or DMS package.

Reorganization

Reorganization is the capability to alter the way a database is arranged. Reorganization includes restructuring (changing the logical structure) and reformatting (changing the physical structure). Some examples of reorganization are adding an attribute, changing a relationship between one to one and one to many, and deleting a secondary index [SOCK-79]. A DBMS approach usually has capabilities for reorganization. The DMS approach usually has very little capabilities for reorganization. The Traditional Application System approach does not have these capabilities.

4.3.4 Query Capability and Report Generation

Query Capability

A query capability is the manner in which the data management approach allows users to select and retrieve data. Queries generally use English-like phrasing in their language form, with conditional expressions to specify how the selection of data is to occur. Queries can be qualified by searching for a range of values, existence or non-existence of data in a field, a string of characters, or a phrase. Some queries allow the user to combine and subset multiple files at one time. Many query languages allow the user to update data values of records selected by the selection criteria. The selected records are displayed in some standard fashion such as in tables in a relational DBMS.

The Traditional Application System approach does not have a query capability. The DBMS approach has full query capabilities, while a DMS approach usually provides less of these capabilities than the DBMS approach.

Report Generation

Report generation is the capability of the data management approach to meet the user's reporting requirements. Report generation capabilities include formatting the report horizontally and vertically, specifying title lines and footing lines, column headings, editing of data values for output, line spacing, page numbering, and sorting.

The Traditional Application System approach provides some report writing capability, however those facilities are not widely used. DMS and DBMS approaches provide good report writing capabilities.

4.3.5 Security and Backup/Recovery

Security

Security is the prevention of access, use of data, or programs without authorization [KING-81]. A DBMS usually contains security features which limit access or use of data without appropriate authorization. DBMS's usually support access protection at the database level, file level, and data element level. DMS's and Traditional Application System approaches usually do not automatically provide such features and rely upon available operating system protection.

Backup/Recovery

Backup involves the creation of a copy of a file or database that is saved for reference in case the original file or database is damaged, or the system fails. Recovery is the process of recovering from a destroyed database or a failure in the hardware, software, DMS, DBMS, or application software [COHE-81]. When a Traditional Application System approach is taken, procedures for backup and recovery must be designed as part of the application system. DMS's and DBMS's normally contain some level of support for these operations. DBMS's however contain much more capabilities.

4.3.6 Data Dictionary

A data dictionary system (DDS) is a computer software system that provides for recording, storing, and processing information about an organization's significant data and data processing concepts, objects, persons, events, and processes. The DDS is used in each stage in the lifecycle of an application. Each of the data management approaches may utilize a DDS. In addition, several DBMS's actually contain a DDS as part of their integrated architecture.

The American National Standards Committee is developing a standard on dictionary software [ANSC-84d]. This standard is called the Information Resource Dictionary System (IRDS) and consists of three parts: a Dictionary (data maintained by the IRDS), a Dictionary Schema (the description of the general structure of the data), and a Processing System (command language and screen-oriented menu-driven interfaces for the user).

4.3.7 Graphics

Computer Graphics is the ability to output graphical entities, control the appearance and position of those graphical entities, obtain graphical input, and inquire about the capabilities and states of the graphics system. Some of the most popular graphics applications produce charts, graphs and diagrams from the data. Some DBMS's and DMS's have, or interface with, graphics application packages that perform some of these functions. In the future it is expected that graphics capabilities will be more widely and directly available for DBMS and DMS approaches in that results of queries will be represented graphically, and graphical input techniques can be used in designing databases.

The American National Standards Committee has a proposed standard on computer graphics called GKS [ANSC-84c]. GKS is a two dimensional graphics standard that comes with a FORTRAN interface. Interfaces to other programming languages are now being developed. It is expected that various application packages will be built upon GKS. Since GKS access occurs only with programming languages and is designed for graphics programmers in building application systems, it must be considered a Traditional Application System approach.

Using GKS with DBMS or DMS approaches is not prohibited. DBMS and some DMS approaches have programming language interfaces that can invoke GKS functions.

4.3.8 Screen Interface

A screen interface is the capability for formatting a CRT screen or display for input or output. The Traditional Application System approach can be implemented with a screen interface, however, it must be programmed into the system by data processing professionals. Some DMS's also contain a screen interface. Many DBMS's contain a screen interface that is rather easy to use and can be reasonably defined by application specialists without data processing professionals.

4.3.9 Vendor Support

Vendor support is the assistance supplied to the user of a vendor product beyond documentation, program code, and updates. The use of the Traditional Application System approach rarely involves any software packages other than those provided by the hardware vendor, thus requiring little or no additional vendor support other than training. The use of a DMS or DBMS approach will require vendor support. This support should include: training of users; providing users with appropriate documentation of the DMS or DBMS;

providing aid in the installation of the package; and, helping users with any problems which arise while using the package. In addition, the DBMS vendor may provide assistance in designing the initial databases to be implemented.

This group of specific factors represents the important issues involved in most data management evaluations. All the factors may not be pertinent to every situation, but they are included to provide a general set. Other factors, not expressly stated here, which may be important in any one setting should be added to the list of evaluation factors. Individuals who are familiar with the user requirements and constraints of the involved DP facility should be consulted in the review and selection of key factors. It is important to keep the number of evaluation factors small, and to use factors which represent mandatory requirements for the planned system. Figure 4-2 portrays typical, implied subjective ratings for the three data management approaches in terms of these specific factors.

SPECIFIC FACTORS	Traditional Application System	DMS	DBMS
Hardware and Software Constraints			
Availability on mainframe/mini	Good	Fair	Fair
Availability on microcomputers	Good	Fair	Poor
Minimum resource utilization	Good	Fair	Poor
Performance and Costs			
Application tuning	Fair	Fair	Good
Tools to monitor performance	Poor	Poor	Good
Low non-recurring costs	Fair	Poor	Poor
Low recurring costs	Fair	Fair	Fair
Maintenance and Reorganization			
Ease of program maintenance	Fair	Good	Good
Ability to restructure and reformat	Poor	Fair	Good
Query and Reporting			
Query capability	Poor	Fair	Good
Report generation	Fair	Good	Good
Security and Backup/Recovery			
Security	Poor	Poor	Good
Backup/Recovery	Poor	Poor	Fair
Data Dictionary	Fair	Fair	Good
Graphics			
Available standards	Fair	Poor	Poor
Application-oriented	Poor	Fair	Fair
Screen Interface	Fair	Fair	Good
Vendor Support	Fair	Good	Good

Figure 4-2. *Implications of specific factors*

5. EVALUATING DATA MANAGEMENT ALTERNATIVES

5.1 Evaluation and Framework

The two previous chapters introduced important issues that a Federal DP manager must consider during an evaluation of data management alternatives. Those issues can be grouped into five tasks:

Task 1. Gather User Requirements, and Gather Hardware, Software, Staffing, and Cost Constraints.
Task 2. Assess Organizational Setting.
Task 3. Assess Global Factors.
Task 4. Assess Specific Factors.
Task 5. Perform Cost/Benefit Analysis.

In this chapter these tasks are fit into a framework for comparing candidate data management approaches. The major components of this framework are illustrated in figure 1-1. The emphasis in this framework and in the previous supporting chapters is on pragmatic guidance that Federal DP managers can use to perform an assessment of data management alternatives. The Federal DP manager will need assistance in gathering user requirements, surveying the availability of commercial packages for the various data management approaches, and in performing a cost/benefit analysis.

Task 1 involves obtaining the organization's user requirements in a requirements analysis. Hardware, software, staffing, and cost constraints should also be obtained at this time.

Task 2 (see ch. 3), assessing the organizational setting and stage of growth, can be done before, during, or after Task 1. The results of Tasks 1 and 2 are made available to Task 3, assessing the global factors. In Task 3 (see ch. 4, sec. 2) the six global factors are assessed. After completing Task 3 the Federal DP manager should have a good insight into feasible data management alternatives, and in many cases, should be able to identify the preferred data management approach. If a selection is made in Task 3, then the Federal DP manager can proceed to Task 5, the cost/benefit analysis.

If the assessment in Tasks 2 and 3 does not identify a suitable data management approach, then the DP manager should proceed to Task 4. Task 4 (see ch. 4, sec. 3) deals with the evaluation of the nine specific factors that are valuable in the comparison and evaluation of the remaining candidate approaches. Additional specific factors should be added as needed based upon the user requirements analysis.

The results from Task 4 are a minimum set of selected alternatives. The one or more data management approaches that remain are passed to Task 5, the cost/benefit analysis. Guidance in performing a cost/benefit analysis can be found in [FIOR-78] and [PERR-82]. The results from Task 5 are a recommended data management approach.

6. CONCLUSION

This Guideline assists the Federal DP manager in the identification and selection of a data management approach appropriate to organizational requirements. Chapter 1 describes the three major data management approaches: Traditional Application System, Database Management System, and Data Management System. Chapter 2 provides a requirements estimate for the number of data management approach selection decisions that will be made over the next 5 years. The estimate is over 30,000 new data management systems will be installed in the Federal Government by 1990. Chapter 3 introduces the organizational context in which most Federal data management decisions are made, and compares that context to the three data management approaches. Chapter 4 identifies and defines Global Factors (data sharing, data usage pattern, data volume, data structures, staffing, and conversion) and Specific Factors (hardware constraints, software constraints, performance, costs, maintenance, reorganization, query capability, report generation, security, backup/recovery, data dictionary, graphics, screen interface, and vendor support) that should be considered during the evaluation process, and provides guidance on their use. Chapter 5 provides a framework for assessing and selecting data management alternatives.

By using this Guideline to select a preferred data management approach, the Federal DP manager has provided a sound base for further technical evaluation by assuring that major factors in determining the success of an organization's application systems have been given the proper consideration. Thus future investments in application development, training, and software procurements have been protected to the maximum degree possible.

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