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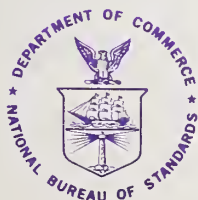
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SCIENCE & TECHNOLOGY:



DATABASE ADMINISTRATION: CONCEPTS, TOOLS, EXPERIENCES, AND PROBLEMS



NBS Special Publication 500-28
U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

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COMPUTER SCIENCE & TECHNOLOGY:

Database Administration: Concepts, Tools, Experiences, and Problems

Belkis Leong-Hong
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TABLE OF CONTENTS

Page

1.	INTRODUCTION	1
2.	DATABASE ADMINISTRATION CONCEPTS	2
2.1	Database Administration Functions	3
2.2	The Database Administrator	6
2.2.1	Functional orientation	6
2.2.2	Scope	7
2.2.3	Stage of implementation	7
2.2.4	Organizational Placement	7
3.	THE DATABASE ADMINISTRATION TOOLCHEST	8
3.1	DBMS and DED/D	8
3.1.1	Database Management Systems	9
3.1.2	Data Element Dictionary/Directory Systems .	10
3.1.3	DED/D Relationship to DBMS	10
3.2	Other Database Administration Tools	10
4.	SURVEY	14
4.1	Background	15
4.2	Functions	16
4.3	Tools	23
4.3.1	Use of DBMS and DED/D	23
4.3.2	Use of Other Database Administration Tools.	25
4.4	Problems	25
4.4.1	Non-Technical Problems	25
4.4.2	Technical Problems	26
4.5	Advice	27
5.	OBSERVATIONS	28
6.	IMPLICATIONS OF DBA COMMITMENT	29
6.1	What Database Administration Should Do For Management	30
6.2	What Management MUST Do for the DBA	31

FIGURES

1. Government DBA's Role in Database Administration Tasks -- Group A	18
2. Government DBA's Role in Database Administration Tasks -- Group B	19
3. Government DBA's Role in Database Administration Tasks -- Group C	20
4. Government DBA's Role in Database Administration Tasks -- Group D	21
5. Availability of Software Tools to Sample DBA Population	24

APPENDICES

APPENDIX A -- BIBLIOGRAPHY	32
APPENDIX B -- DBA INTERVIEW OUTLINE	36
APPENDIX C -- DATABASE ADMINISTRATION TASKS -- INTERVIEW OUTLINE	38
APPENDIX D -- DATABASE ADMINISTRATION TOOLS -- INTERVIEW OUTLINE	41

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DATABASE ADMINISTRATION:
CONCEPTS, TOOLS, EXPERIENCES, AND PROBLEMS

Belkis Leong-Hong
and
Beatrice Marron

In this report the concepts of database administration, the role of the database administrator (DBA), and computer software tools useful in database administration are described in order to assist database technologists and managers. A study of DBA's in the Federal Government is detailed in terms of the functions they perform, the software tools they use, the problems they have encountered, and advice they offer. Finally, some guidelines are presented on what database administration should do for management, and what management must do for their DBA's.

Key words: Computer software; database administration; database administrator (DBA); database management system (DBMS); data element dictionary/directory (DED/D).

1. INTRODUCTION

Increased awareness of managers that data is an organizational resource has led to a recognized need for disciplined control of all automated and non-automated data. This control is embodied in a set of management procedures and technical functions which is characterized as "database administration". At the present time the term database administration is applied to a conglomeration of duties and responsibilities for which there exists no standard. There is much interest in this emerging discipline, both inside and outside the Federal Government.

The National Bureau of Standards (NBS) is charged under the provisions of Public Law 89-306 (the Brooks Act) to assist Federal information managers in their data processing needs. NBS assesses new developments in information and computer sciences and technologies, in order to help other agencies apply technological solutions to data

processing problems. Several recent NBS studies in the data management area have focussed on software tools such as data element dictionary/directory (DED/D) systems and database management systems (DBMS) [1, 19, 26, 27].

In this report, concepts and functions of database administration are examined. Tools useful to the practicing database administrator (DBA), and problems common among DBA's are discussed. Critical needs and common pitfalls are identified to provide guidance to the database technologist, the manager, and the new DBA. A bibliography of relevant literature is included as Appendix A.

To gather experiential data for this study, we consulted DBA's in the Federal Government. These DBA's were very candid about the problems to be expected in establishing a viable database administration operation, and they provided insight into the rewards of an effectively controlled database environment. Their cooperation is greatly appreciated. Although the sample was small and from a specialized community, the observations made are applicable to the entire database community.

2. DATABASE ADMINISTRATION CONCEPTS

Database administration encompasses all the technical and management activities required for organizing, maintaining and directing the database environment. Throughout this report "Database" is used to mean "all of the data of the organization which is organized and controlled using a database technology," or "a systematic methodology for the standardization and integration of data resources at an organization level" [28]. A database environment consists of:

- * the database, as defined above, including automated and non-automated data;
- * the database administrator (DBA), the manager of the database environment;
- * the software tools used in data administration and data processing; and
- * the users of the database.

It should be noted that while a DBMS is a very useful tool for database administration, the mere usage of a DBMS does not constitute establishing a database environment.

The main goals of database administration are: to optimize usage of data in a shared database environment; to incorporate a systematic methodology for the centralized management and control of data resources; and to balance conflicting objectives with respect to the organization's mission and the overall economy of data handling. Among the key requirements for effective database administration are: strong management commitment and support; technically competent staff; team participation in the database environment by DBA's, management, technical staff, and users; and a well-defined Database Master Plan. This Master Plan must be developed early, and must include: plans for transition into a database environment, for staffing, and for acquisition of systems and services; definition of responsibilities; and rules and procedures for operation. Significant advantages that database administration can provide are:

- * The database can be better managed, especially if the data resources are centralized and shared;
- * Data independence can be accomplished via controlled definition, design and implementation of the database;
- * Data redundancy and inconsistency can be reduced by balancing conflicting requirements;
- * Data integrity can be improved via standard usages, increased data reliability, and enforced security restrictions;
- * Increased responsiveness to the various user communities can result from better controlled, and more up-to-date data; and
- * Economic benefits can be derived from elimination of unnecessarily duplicative processing.

The degree to which database administration should be applied depends on the size and complexity of the databases, and the information needs of the overall organization. However, proliferating databases, overlapping requirements, lack of data integrity, and duplication of efforts are symptoms of the need for database administration.

2.1 Database Administration Functions

There is wide agreement on the basic functions of database administration. A list of tasks most commonly performed by the DBA was compiled from the literature, and is presented below [4, 5, 6, 9, 22, 23, 29, 34, 35, 37, 38]. This list of functions is not exhaustive, but it is

representative.

1. Database definition/ redefinition. The DBA should identify and define common data elements, define the relationships between data elements and other components such as programs, files, and systems. The definition of the data elements and the data relationships should be based on a clear understanding of each participating user community's requirements, as well as the overall organization's needs. Where possible, the DBA uses a data definition language to define and structure the database. It is also in the DBA's purview to define, review and monitor data standards. If the need arises for changing and re-structuring the database, the DBA should initiate this activity, and redefine the database, or any part of it to meet changing requirements.

2. Selection and procurement. The DBA should participate in the processes of evaluation, selection, and procurement of hardware, software, and services related to database administration.

3. Database design/ redesign. The main design activity is the design and structuring of the entire database, taking into consideration the differing needs of the entire user community. This includes design of the data structure as seen by the application community, the storage structure, mapping and search strategies, and access methods, as well as design of the DED/D and of support software for creating, maintaining, and reorganizing the database. If the need arises, redesign and restructuring activities, encompassing all the elements above are also the DBA's responsibilities.

4. Database creation. Under this function are included such activities as data collection, database loading and testing, and implementation of data definitions, the DED/D and other database support software.

5. Database Security/Integrity. The database security function is intended to guard against unauthorized access to the database, and unauthorized update, copying, removal or destruction of any part of the database. This may be achieved through the use of security locks and keys, cryptography, etc. Database integrity is related to the DBA's responsibility for the correctness and accuracy of the data. It can be achieved through the use of validation checks, loggings, dumps, backup and recovery procedures, and auditing procedures.

6. Database maintenance/management. The DBA should be responsible for the continued well-being of the database environment. As such, it is his responsibility to maintain and update database definitions and database documentation, and to maintain and update the DED/D and other database support software. The DBA should interpret and administer high level management policies related to the database, and define rules of use and access constraints for the database. In addition, he should be responsible for review, and approval of new data definitions and enforcement of data standards.

7. Database performance monitoring and evaluation. Responsibilities should include reviewing, testing, and evaluating the performance of automated as well as procedural data activities; initiation of system improvement when indicated; assessment of the impact of changes; and maintenance of state-of-the-art awareness. If the performance evaluation and monitoring activities indicate that the database is no longer effective or efficient in the present configuration, redefinition, redesign, and restructuring activities may be undertaken.

8. Database enforcement. Enforcement activities include determination of compliance with established standard usages; development of database content, organization, and storage control procedures; and responsibility for access control and security of the database, such as password issuance.

9. Liaison with users, with systems and application analysts, and with organizational management should provide information, assistance and guidance on the use of database facilities, to detect and correct user problems, and to notify users of changes in system status.

10. Training of users, staff and management should be coordinated to develop awareness of database concepts, and available resources.

There is another category of functions which is typically performed before the database environment is operational. This category of initiation functions includes such activities as planning, formulating a Database Master Plan, performing feasibility studies, personnel staffing, and negotiating participation in the database environment with different groups of users.

2.2 The Database Administrator

The DBA, in theory, is the organization's leader in planning, design, development, implementation, testing, documentation, operation, and maintenance of the entire database environment. The role of the DBA is usually characterized as both technical and administrative. There is also a promotional dimension to this role, since the DBA represents the database administration concepts and procedures to all participants, and coordinates all database activities among managers, analysts, systems and application programmers, and users. Because database administration activities impact across organizational boundaries, the DBA position is sensitive, and the DBA must be astute to jurisdictional questions and competing mission requirements. It should be noted that although the tasks in database administration are performed by one or more persons, there is usually one person who is charged with the responsibility for coordinating, controlling and directing activities in the database environment. This person is generally designated as the DBA.

Although there is agreement on the basic functions of database administration, there is no standard set of duties and responsibilities for the DBA. Several factors that influence the definition and extent of the DBA role within an organization are:

- a) functional orientation,
- b) scope,
- c) stage of implementation, and
- d) organizational placement.

All these factors depend on the degree of commitment to the database environment by the implementing organization. In order to characterize fully a DBA, it is necessary to describe him in terms of the four factors mentioned above. Together, these determine the role of the DBA, and the functions that are performed and emphasized.

2.2.1 Functional orientation. There are two extremes of functional orientation:

- a. Technical: The DBA manages the database, he has an extensive technical background, and is responsible primarily for the technical operation of the database environment.
- b. Administrative: The DBA is a manager, who may or may not have detailed technical background. Usually the administrative DBA has a staff of technical personnel that handles the technical day-to-day operations of database administration.

In practice, none of the DBA's is strictly technical or strictly administrative, but a combination of the two. As mentioned before, there is also often a promotional orientation in the DBA function.

2.2.2 Scope. It is inevitable that factors such as the mission of the database administration effort, the database environment, and the size of the organization will have significant influence on the scope of the DBA. Scope can fall into two categories:

a. Project-oriented: The project DBA has complete responsibility and control for all database-related issues pertaining to that project. The project DBA sometimes reports to an overall-organization DBA. The term "local" DBA has also been used to refer to the project DBA.

b. Overall-organization-oriented: The organizational DBA has complete control and responsibilities for all database-related issues for the corporate data resources. Such DBA's are usually placed very high organizationally. The term "global" DBA has also been used to refer to the organizational DBA.

2.2.3 Stage of implementation. Although stage differentiation is an ephemeral characterization, it is of interest in the context of differences in the DBA functions. The stages of implementation are: initiation, design, and operation.

Activities performed by DBA's in each of these stages will differ in their emphasis. For example, during the initiation stage, activities such as feasibility studies, planning, and system selection will be predominant; as the database administration function progresses to the operational stages, performance monitoring and evaluation activities, maintenance and management activities, and efficiency improvement activities will predominate. All the while, the ten basic functions outlined in the previous section are performed to some degree.

2.2.4 Organizational Placement. The consensus among data resource technologists is that the DBA function should be placed very high organizationally in order to ensure its success. Three examples of organizational placement are presented below:

In the first example, the DBA is located in the director's office. Placed that highly, the DBA can have a great amount of clout, since the office at least implicitly has the direct support of executive management. As a part of the director's staff, the DBA should have access to the organizational data resources and can exact cooperation from the line organizations.

A second example is the DBA as a staff position in the Comptroller's Office. A direct line of communication to the Comptroller could have great leverage, since the "purse string" can be used as a lever in assuring compliance to database rules and regulations.

A third example pictures the DBA as a sub-unit of the data processing shop. This represents the lower end of the spectrum in organizational placement. As a staff member of a service unit, the DBA usually would have less authority organization-wide than in either of the two cases mentioned above, and can expect less cooperation from the rest of the organization.

3. THE DATABASE ADMINISTRATION TOOLCHEST

There are a great number of software packages available in the market that can help the DBA. The use of these tools can have direct impact on all phases of the management and control of data resources. Two software tools are considered to be greatest in importance in database administration. These are: the Data Element Dictionary/Directory (DED/D) system, and the Data Base Management System (DBMS), both of which are discussed below. Then, descriptions of other database administration tools and auxiliary tools are presented.

3.1 DBMS and DED/D

Database Management Systems (DBMS) and Data Element Dictionary/Directory Systems (DED/D) are two "core" tools for the DBA, and complement each other in the management of the database environment. In fact, many of the benefits realized from the use of a DED/D are parallel to the ones attributed to the use of a DBMS. However, it should be noted that while the benefits realized from a DBMS are directly related to the effective computer processing of the data; the benefits from a DED/D are directly related to the effective collection, specification and management of the total

data resources of an organization.

Among the tangible benefits that can be derived from the use of a DBMS and a DED/D are [19, 27]:

- * Sharing of data resources;
- * Simple and effective control of the data elements;
- * Reduction of data redundancy and inconsistency;
- * Enforcement of standard definitions and usages;
- * Enforcement of security safeguards and controlled accessibility to the database;
- * Maintenance of data integrity;
- * Determination of the impact on the total information activity from changes to data elements;
- * Resolution of conflicting requirements;
- * Centralization of data elements as an aid in design and development of new systems; and
- * Consistency in documentation for the database.

It should be noted that it is not an absolute requirement that those subscribing to the concepts of database administration must use a DBMS or a DED/D. However, experience shows that when the database environment becomes operational, plans are made to procure either one or both of these tools. Some advocate the phased installation of these two tools, with the DED/D preceding the DBMS. But regardless of the stage at which these tools are installed, their fundamental importance cannot be overly emphasized.

3.1.1 Database Management Systems . A DBMS is a software tool that provides an integrated source of data for multiple users, while presenting different views of the data to different users. It can be characterized as generalized software which provides a single flexible facility for accommodating different data files and operations, while demanding less programming effort than conventional programming languages [19]. It features easy access to the data; facilities for storage and maintenance of large volumes of data; and most importantly, the capability for sharing the data resources among different types of users.

Database Management Systems range from elementary systems with single record structures, providing rudimentary report formatting facilities, to very elaborate systems handling several files with hierarchical structures, performing functions in an online mode, and having sophisticated query and report-writing capabilities.

3.1.2 Data Element Dictionary/Directory Systems. As data resources continue to grow, it is becoming apparent that not all data problems are necessarily resolved with the use of a DBMS, especially, since not all the data is automated. A recent trend is to use a separate class of automated tools that provide central control of all data resources in a uniform manner across organizational lines, the Data Element Dictionary/Directory systems. The DED/D performs some of the same functions as the DBMS; however, it is different in that the thrust of the DED/D is to provide control over ALL the data resources, both automated and non-automated. Since the design objectives of the DED/D coincide with the basic goals of database administration, it is not surprising that the DED/D is one of the basic tools in the DBA toolchest. Two recent NBS Special Publications survey the state of the art in DED/D's [26, 27].

3.1.3 DED/D Relationship to DBMS. Because DED/D's are concerned with the management of data elements, it is logical that there should exist a strong relationship between a DED/D and a DBMS.

Interfaces enhance the usefulness of both the DBMS and the DED/D, and in fact, many of the commercially-available DED/D's provide interfaces to various DBMS's. These interfaces provide the user with the ability to [27]:

- a) Define the database to the DED/D, capitalizing on DBMS resources, such as existent, well-defined file structures and access methods;
- b) Generate data element definitions for a DBMS from an up-to-date DED/D; and
- c) Exercise control over the data elements of a DBMS using DED/D facilities.

3.2 Other Database Administration Tools

Tools which are useful primarily in database administration are described below in terms of their functions. It is important to note that these software tools may appear as a single, self-contained piece of software; as a part of another piece of software; or as a utility or facility of

the DBMS, the DED/D, or the operating system.

Information/Data Retrieval System

An information/data retrieval system (IRS) is a program or set of programs that enables the user to retrieve information in a variety of formats. Some IRS' operate in batch mode. However, most modern IRS provide interactive (conversational) capabilities, including extensive user-oriented facilities and rapid response to system commands.

Online Query System

An online query system is a separate set of programs, or a feature within a DBMS, that enables the user to obtain information contained in a database interactively.

Data Entry System

A data entry system provides the facilities for automatic data entry and data collection. Some provide interactive data entry facilities, allowing for key verification, limited editing, and formatting. Some allow batch operation to enable massive data loading.

Editor

An editor facilitates selective modification and correction of data, program or document text. Special purpose editors are available, geared towards entry, modification and editing of data, files, programs, or texts. Facilities may be provided to edit input transactions against a set of predefined validation criteria.

Flowchart Generator

A flowchart generator produces a pictorial diagram of the flow of control and logical paths of a computer program. Narrative documentation may be produced as a side-benefit.

Text Processor

A text processor is a documentation aid that accepts lines of source texts interspersed with format control commands, and formats the text into a printable, paginated document with a user-designed style.

Report Generator

A report generator allows automatic generation of pre-formatted reports on a production basis, or allows definition of ad-hoc reports, via parameters. Some rudimentary data manipulation functions may be performed, and data extraction from an established database may be possible.

Cross-Reference Generator

A cross-reference generator for databases produces listings of data elements used in files, programs and systems, indicating where data elements are being referenced. For programs, it produces listings of the variables (data elements) used in programs, subroutines, and systems, indicating where they are being referenced.

Text/File Reformatter

A text/file reformatter rearranges and structures files according to specifications, and rearranges and structures text and source programs for improved readability. It may provide limited text additions for documentation purposes.

Data/File Maintenance Programs

Data/file maintenance programs perform global changes for all, or selected, records in a file, while reporting changes in data content before and after operations. They may provide data/file edit capabilities, and data items deleted or added may be flagged for audit trail purpose. Data and file maintenance programs may be a self contained software package, a set of utility programs provided by the operating system, or a feature of the DED/D or the DBMS.

Data Editing and Validation System

A data editing and validation system provides the user with the ability to perform data validity tests, data editing, error correction and error reporting, or any subset of these tasks. It may be parameter-driven, so that different edit requirements can be accommodated. These functions may be performed in an entirely interactive manner, or completely batch, or a combination of the two modes.

Data Auditor

A data auditor examines source data definitions and analyzes data relationships, data structures, formats and storage usages for consistency, validity, and efficient utilization. It may provide a dictionary or a catalogue that contains definitions of the data attributes, and characteristics of the data type. The data auditor is available as a self-contained software product, but it is also available as a feature of the DED/D or the DBMS.

Data Security

A data security module may provide protection over sensitive data, by encrypting/decrypting, and by controlling access to the sensitive parts of the database. Data security can be achieved through encoding and decoding, or through execution-time password capabilities.

Test Data Generator

A test data generator produces test data files according to specifications. The test data can then be used for testing application software.

Optimizers

Optimizers apply changes directly to program source code in order to make them run more efficiently in terms of reduced run-time, or reduced core requirements. They may perform analysis of the program for undetected bugs and optimal logical flow.

Automatic Space Generators

Automatic space generators find available space for programs or files that are awaiting processing.

Scheduler

Schedulers allocate available computing resources in order to optimize the use of resources to daily workloads. They may produce reports indicating the areas where optimization of the resources may occur.

Project Manager

A project manager is a software tool that provides data collection, storage, and reporting facilities aimed at personnel time and task accounting. They may be coupled with PERT packages, and other productivity and scheduling management aids.

Librarian (program, file, etc.)

Librarians facilitate organized and economical storage of programs, texts, data sets, and object modules for centralized retrieval and updates. They may collect accounting data to assist in storage allocation.

4. SURVEY

In order to gain insight into the subject of database administration, it was decided to go into the ADP community, and talk to people who perform the functions of database administration. The study was limited to in-depth conversations with twelve DBA's from the Federal Government in the Washington, D. C. area. All the meetings took place in mid-1977. The agencies represented were:

Civil Service Commission
Department of Agriculture
Department of Commerce-- NBS
Department of Defense-- DCEC
Department of Defense-- MILPERCEN
Department of Defense-- NAVY
Department of Health Education and Welfare--
-- Social Security Administration
Department of Housing and Urban Development
Energy Research and Development Administration
Federal Deposit Insurance Corporation
Federal Power Commission
Treasury Department

There is usually more than one person in an organization performing database administration functions, and in fact, often several members of the organization were present at our meetings, presenting us with a broader and more objective picture of database administration within that organization. The discussions were conducted using a structured approach, but on an informal level. An outline had been prepared and is included as Appendix B. The DBAs were

given lists of the functions, and tools discussed in the previous sections; these lists are included as Appendices C and D.

The discussions were organized in five areas: background, tasks, tools, problems, and advice; and this section follows that scheme. A composite case study is presented, rather than individual case studies. Similarities and differences are analyzed in terms of the DBA functional orientation, scope, stage of implementation and organizational placement.

4.1 Background

A summary profile of our sample of Federal DBA's follows:

There is not yet within the Government a position classification entitled "Database Administrator." All of the DBA's interviewed have a Civil Service Commission classification of "Computer Specialist," "Database Analyst," or "Computer Systems Administrator," which falls in the GS-334, 330, or 301 classification series. Some had the classification sub-title of DBA. In more than half the cases, the person's organizational title is DBA. The interviewees were equally divided between male and female. They consider themselves administrators, although they usually have a technical/computer background. The lead person is rated GS-13 to GS-15.

The support staff averages 6 in number, and includes both administrative and technical personnel. The staff's training is usually technical, enhanced by vendor-provided courses, and supplemented by users groups meetings and conventions.

75% of those interviewed consider themselves over-all organization-oriented rather than project-oriented; one half of these had other project-oriented DBA's reporting to them. There were varying degrees of control over project information.

In about 40% of the cases, the DBA function was operational; the rest were in various stages of initiation, design and development. Those that were operational had been in existence from 1-1/2 years to 4-1/2 years. The date of creation of the function frequently was preceded by extensive unofficial initiation activities, ranging from 12 to 18 months. Those that were in the initiation phases were 6 to 12 months old. It is interesting to note that in those cases where the database administration function is

operational rather than in the initiation phase, the chief's title is more often DBA, and the grade level is at the higher end of the range.

Those that were in the initiation stages viewed their database administration functions as being technical rather than administrative. Those that have been operational for longer periods, viewed their functions as being both administrative and technical. Further, those with an operational status usually have a Database Master Plan, a better idea of what the DBA tasks involve, and fairly well-defined responsibilities.

The database administration activity is usually located within the data processing/information management area of an organization; it is most often separate from, but on a par with, the computer operations activity. Sometimes, there is a tie to the comptroller's office, or to the office of the director for administration.

Reasons cited for creating the database administration function fall into two categories:

- (1) General commitment to database and database concepts, i.e., looking at things that would help in data management, fulfilling a Database Master Plan, pooling data resources, and concentrating database expertise in-house.
- (2) To solve specific problems, such as data redundancy, no data standards, poor data access, and inadequate data control.

4.2 Functions

The ten major tasks discussed in section 2 are grouped here, for analysis, as follows:

- A. Definition, Design, Implementation;
- B. Maintenance/Management, Performance Monitoring and Evaluation
- C. Security/Integrity, Enforcement;
- D. Selection/Procurement, Liaison, Training.

The order in which these appear do not indicate their relative importance or life cycle position.

Barcharts depicting the government DBA role in database administration tasks are presented in figures 1-4. There is a barchart for each of the groupings cited above.

The following legend applies to all the bar-charts:

Direct responsibility: _ indicates a major role;

Coordinating role: ranges from strong participation in a team effort to an advisory/consulting role;

Other: means that other groups within the overall organization perform this function;

Not applicable: tasks are not relevant to the organization.

It should be noted that the legend items on the bar-charts are not mutually exclusive. Even when direct responsibility for a specific task was claimed, there was some measure of consultation or team effort reported. When "Other" is noted, it may mean a standards group, a computer operations group, or an end-user performs this function. "Not Applicable" means the activities are not being performed at the present time by anyone in that organization. For example, if a DED/D does not exist in an organization, none of the activities related to the DED/D are applicable. We report the DBA's statements regarding direct responsibility and coordinating role, but realize that there is often only a small discernible difference between the two roles.

FIGURE 1

GOVERNMENT DBA'S ROLE IN DATABASE ADMINISTRATION TASKS-- GROUP A

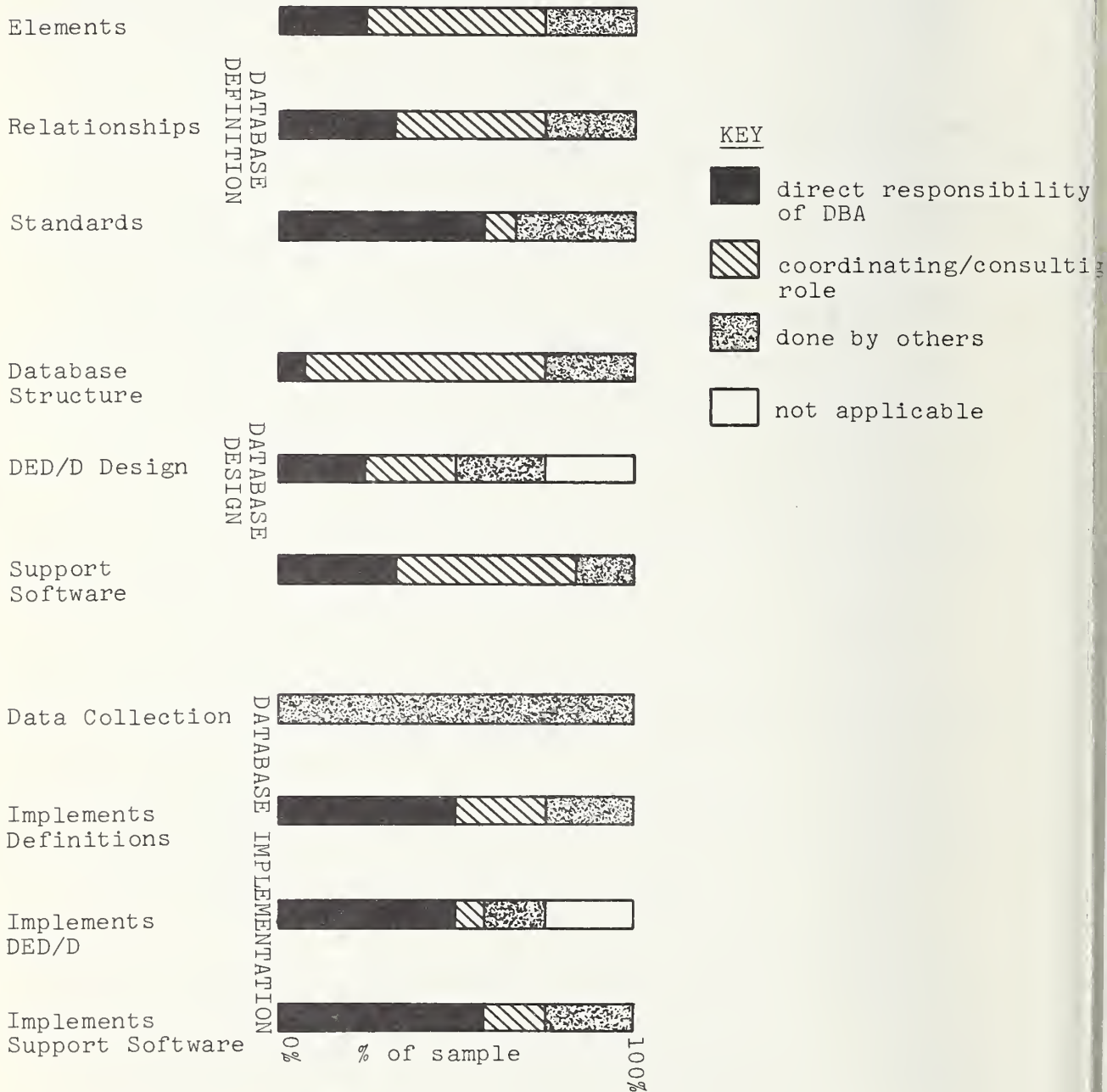


FIGURE 2

GOVERNMENT DBA'S ROLE IN DATABASE ADMINISTRATION TASKS--GROUP B

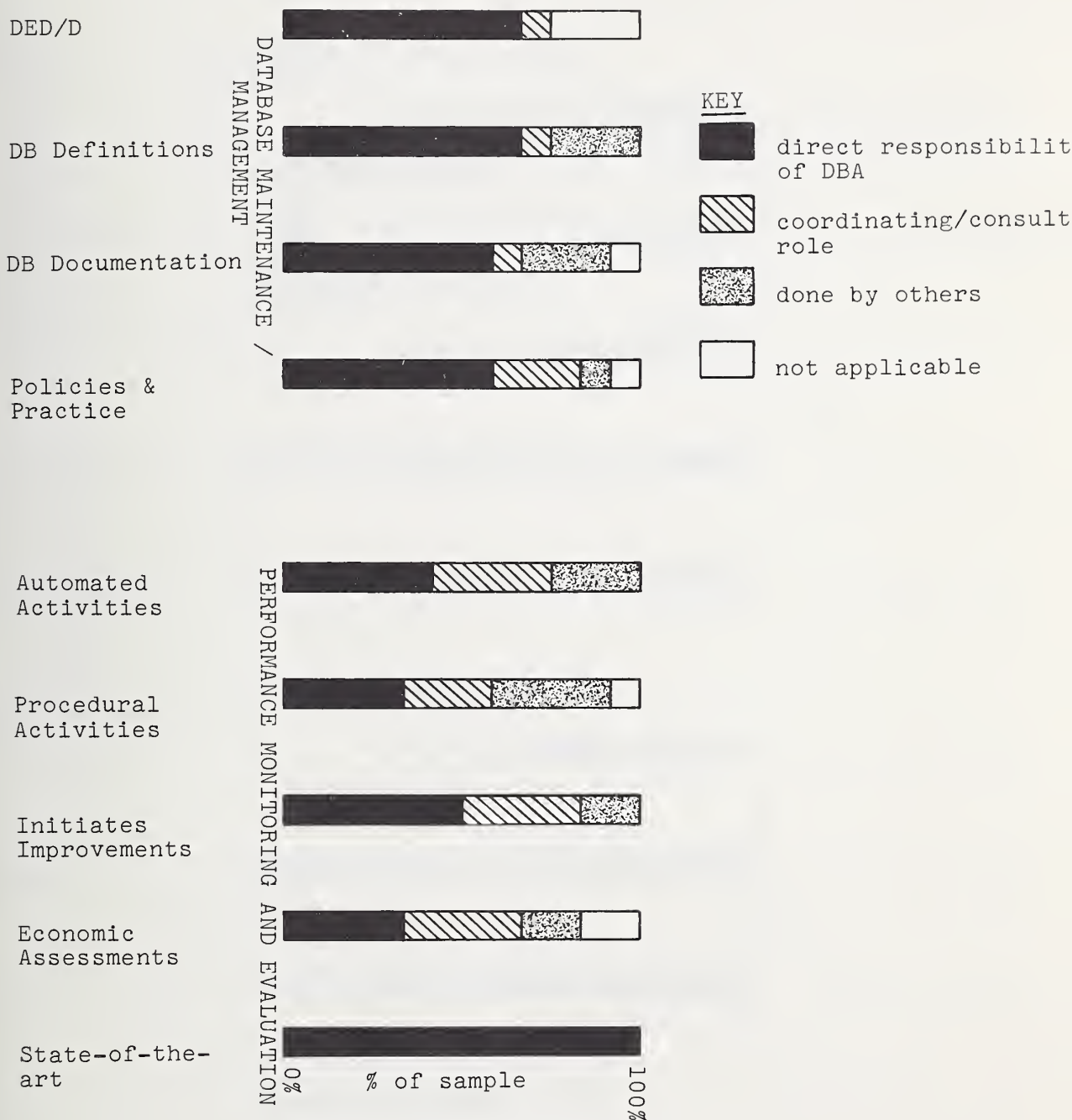


FIGURE 3

GOVERNMENT DBA'S ROLE IN DATABASE ADMINISTRATION TASKS--GROUP C

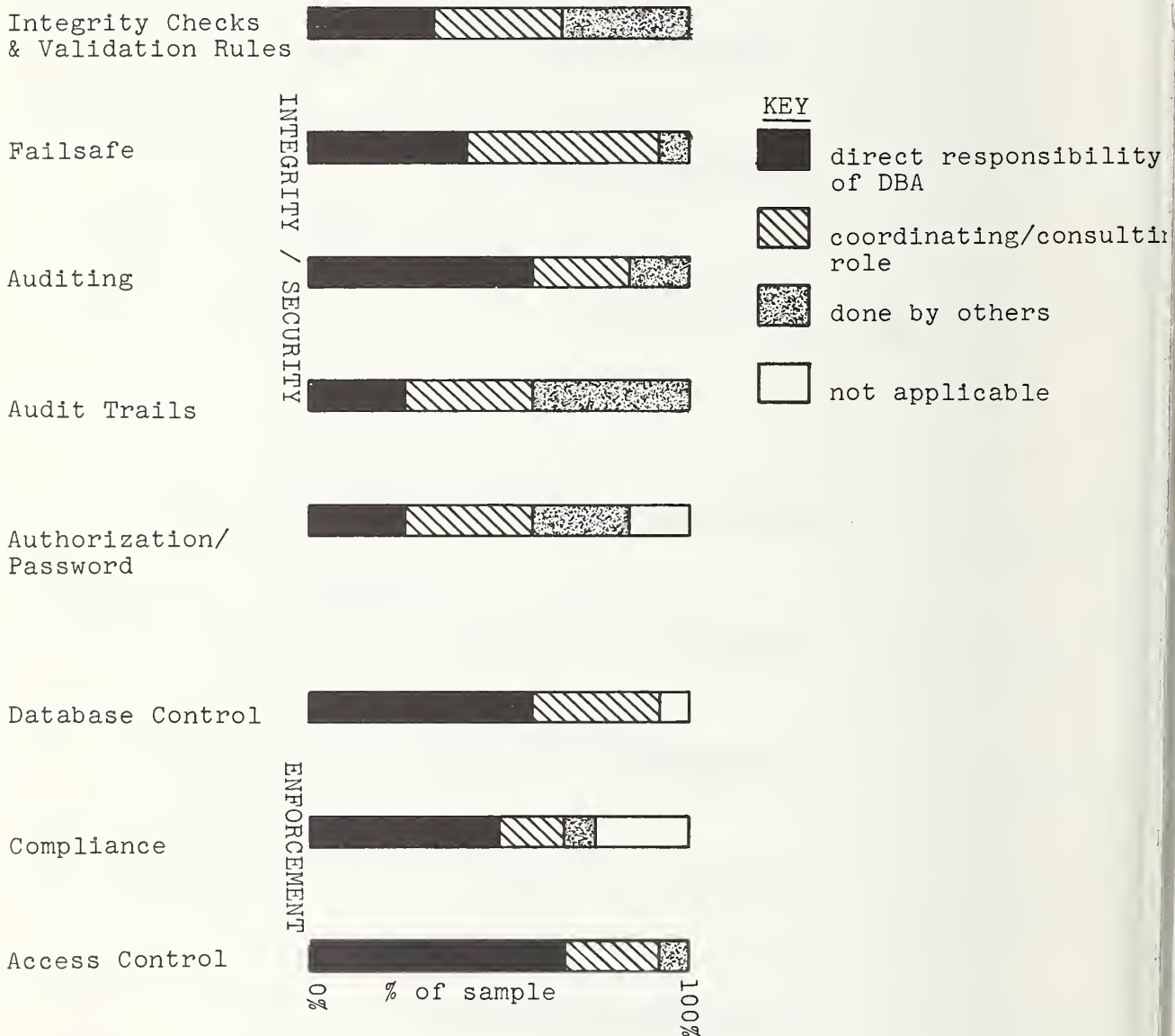
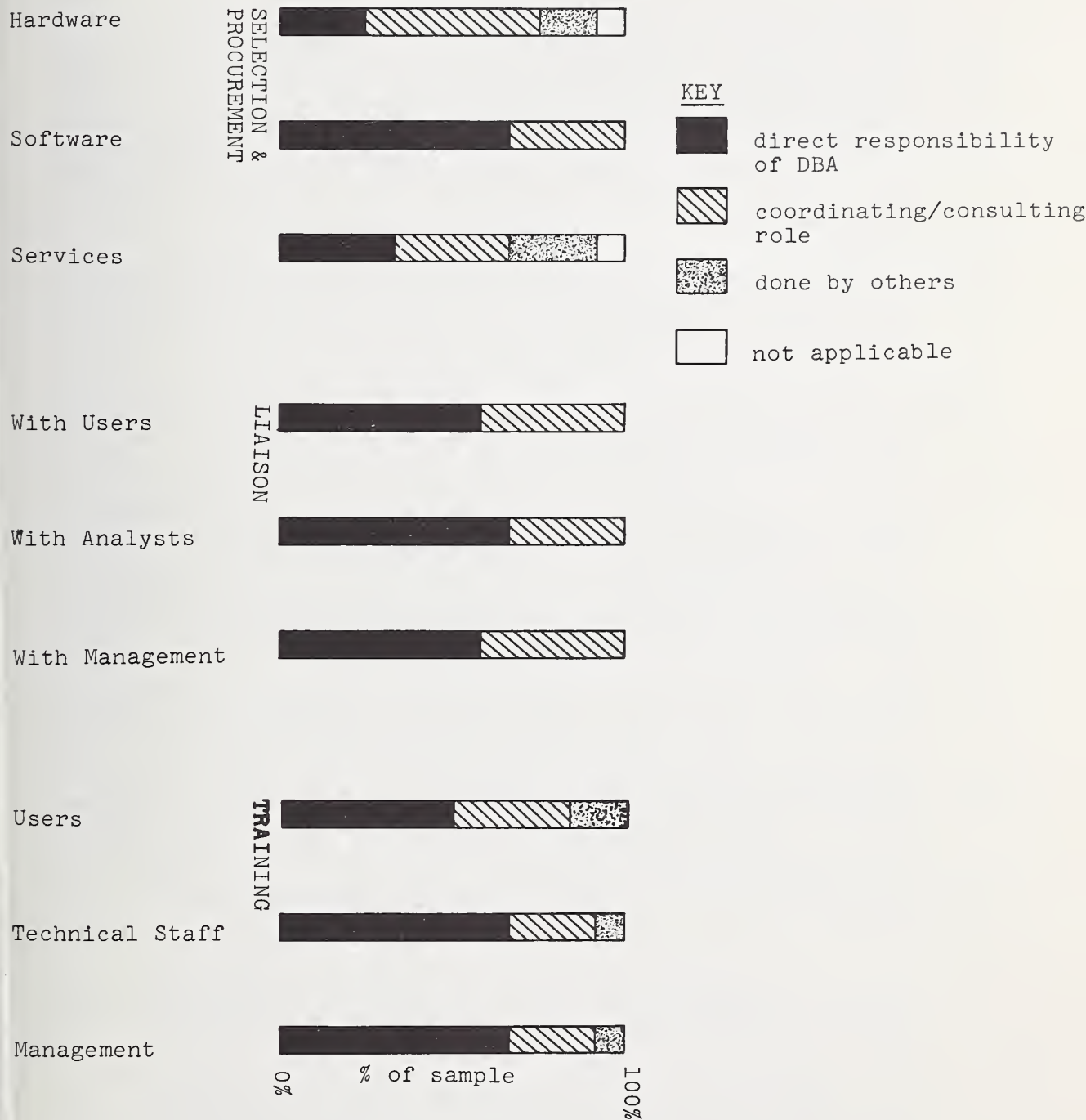


FIGURE 4

GOVERNMENT DBA'S ROLE IN DATABASE ADMINISTRATION TASKS--GROUP D



In addition to being asked to identify which tasks they performed, the DBA's were asked to identify tasks "most often performed" and tasks deemed "most important." The term DBA here means the DBA team. The following patterns were observed in the sample.

- * In 75% of the activities, the DBA either has direct responsibility, or a coordinating role. The notable exception is in the area of data collection. Those surveyed indicated that the task of collecting data was performed or overseen by other than the DBA. Data collection was included among the DBA tasks because it was so reported in the literature. A possible explanation for this discrepancy is that the literature reports on industry experience, whereas our sample covers Federal DBA's only.
- * In database maintenance/management and database performance monitoring/evaluation activities, the DBA has either direct responsibility or coordinating responsibility in 75% of the sample population.
- * There is a very small role reported in the database documentation area, although the responsibility clearly lies within the DBA's domain.
- * Although liaison, selection/procurement, enforcement, security/integrity, and training activities are almost universally the direct responsibility or strong coordinating responsibility of the entire sample, those activities were, however, seldom reported as being "most often performed" or deemed "most important."
- * "Most often performed" tasks were: design, implementation, and maintenance/management, followed closely by definition and performance monitoring/evaluation activities. Judged "most important" tasks were: design, implementation and definition, in that order. Admittedly, since many activities are time- and stage-dependent, it is difficult to analyze these responses. Very often, the answer to "most often performed" did not correspond with the answers to deemed "most important."
- * Other tasks mentioned included planning, scheduling, document preparation, user requirements definition, and applications development.
- * It is important to point out that the activities that were noted as being "most important" and "most often performed" are the technical activities within the DBA functions. Although the DBA's interviewed claimed that

they were more administrative than technical in nature, in fact, the analysis based on their responses to "most often performed" and "most important" indicate their technical inclination.

4.3 Tools

Although there are many generalized software packages available for sale or lease, some DBA's reported that they chose to build their own software, either because they required special capabilities, because the commercial software was unavailable to them, or because they felt they could build better or cheaper tools in-house.

The availability of software tools to the sample DBA population is summarized in figure 5. This availability is reported in two categories, commercial software and in-house developed software. Within each of these categories, distinction is made between "free-standing" and "feature of other tool." "Free-standing" means that the tool is a self-contained software package; "feature of other tool" means the tool is a capability within another software system, such as a DBMS, a DED/D, or an operating system. The entries in the table are the percentages of DBA's who reported that these tools were available. It should be noted that although tools may be reported as available, they are not necessarily used by the database administration group.

4.3.1 Use of DBMS and DED/D. 92% of the DBA's reported the usage of a DBMS, and the remaining 8% is in the process of procuring one. More than half actually have more than one such system. All have purchased or leased commercial software; sometimes they also have in-house developed systems.

92% of the DBA's reported the usage of a DED/D, and the remaining 8% has plans for procuring one in the future. 75% of the DED/D's are in-house developed software.

It is not surprising that there is almost total use of these two tools, since they are by far the two most important tools in database administration.

FIGURE 5

AVAILABILITY OF SOFTWARE TOOLS TO SAMPLE DBA POPULATION

TOOLS	COMMERCIAL SOFTWARE		IN-HOUSE SOFTWARE		NOT AVAIL
	(% AVAILABILITY)		(% AVAILABILITY)		
	FREE- STANDING	FEATURE OF OTHER TOOL	FREE- STANDING	FEATURE OF OTHER TOOL	
DBMS	92				8
DED/D	25		67		8
Information Retrieval System	42	50	8		
Online Query System	33	50	8		8
Data Entry System	50	17	8		25
Editor		50	25		25
Flowchart Generator	50	17	8		25
Text Processor	33	25	8		33
Report Generator	58	42			
Cross Reference Generator	33	33		17	17
Text/File Reformatter	17	50	8		25
Data/File Maintenance	8	58	25		8
Data Editing/Validation	8	33	42		17
Data Auditor	8	42	17		33
Data Security	25	50	8		17
Test Data Generator	17	8	25		50
Optimizer	25	17			58
Automatic Space Generator	17	67			17
Scheduler		83			17
Project Manager	50	8	8		33
Librarian	50	42	8		

NOTE: The entries are the percentages of DBA's who reported these tools as available.

4.3.2 Use of Other Database Administration Tools. The tools in this section are frequently features of other systems, especially operating systems and DBMS. As such, this group of tools is predominantly reported as being other than in-house developed.

All the tools except the test data generator were reported generally available. Everyone had a report generator and an information retrieval system in the toolchest. On-line query systems and data/file maintenance systems were next in number, followed closely by data editing and validation systems and cross reference generators. 75% reported they have data entry systems, editors, flowchart generators, and text and file reformatters. Most report also the use of text processors and data auditors. Although flowchart generator was a tool that is among those reported most generally available to the DBA, in fact, the DBA's claim it is seldom used.

It is difficult to draw conclusions from figure 5, for although a pattern of availability exists, the amount of actual usage in the performance of database administration functions cannot be generalized.

4.4 Problems

The DBA's were asked to discuss problems they encountered during the course of implementing database administration functions in their organization. Responses varied from "it is too early to tell," to lurid details of specific situations. Problems are summarized in two categories: non-technical problems and technical problems.

4.4.1 Non-Technical Problems. Non-technical problems usually had to do with lack of management commitment, jurisdictional questions, data ownership disputes, power struggles, poor communication, inadequate training, and high costs. Several specific problems are noted below:

- * Lack of commitment to database administration concepts at different management levels;
- * Management hesitant to commit manpower and money to internally-oriented, non-visible projects;
- * Unreasonable management demands;
- * Lack of decision-making power for the DBA;
- * Lack of enforcement power for the DBA;

- * Unresolved jurisdictional problems, especially when different groups perform database administration tasks;
- * Unclear definition of responsibilities of DBA's, analysts, users, and management;
- * Frequent reorganization causing instability in control of data;
- * Undefined ownership and control of data, especially between users and DBA;
- * DBA concepts conflict with service center concepts;
- * Failure to establish effective communication lines between DBA's, technical staff, and management;
- * Insufficient communication between DBA's and users with respect to data errors and availability of help;
- * Decision-making management not knowledgeable in technological state-of-the-art;
- * Lack of training and understanding of database concepts and DBMS by users and technical staff.
- * Lack of experience in database technology.
- * Skepticism with respect to the success of database administration practices;
- * Resistance of analysts and programmers to DBA interference;
- * Excessive procurement constraints on purchase of hardware, software, and services;
- * Inadequate cost-benefit analyses regarding implementing DBMS vs. conventional programming, and in evaluating in-house vs. commercial software.
- * High cost of hardware, software, services, technical staff, training, and vendor support;

4.4.2 Technical Problems. Technical problems tend to be specific to each organization, but some general problem areas are noted below:

- * Generalized systems sometimes too general for specific applications; tailored systems sometimes too inflexible for changing needs;

- * Commercial software sometimes not available for existing hardware;
- * Hardware/software limitations and interface problems;
- * Absence of shared databases in spite of DBMS usage;
- * DBMS used as a file control mechanism rather than a database administration tool;
- * Inability to assure reliability of data;
- * Lack of organizational data standards;
- * Poor system and software documentation;
- * Poor vendor technical support;
- * Too much dependence on vendor support;
- * Non-availability of commercial software source code.

4.5 Advice

The following advice was offered by the practicing DBA's to those about to establish this function. Much of this advice is based on hindsight and may be application-specific. However, it should be helpful to future DBA's since it is based on actual experience.

- * Get complete management support, and get it early;
- * Establish a strong organization, with good lines of communication;
- * Have a good Database Master Plan;
- * Be flexible, and adaptable to change;
- * Develop credibility;
- * Be a combination of a good technician and a good politician;
- * Involve the users in planning;
- * Hire staff with strong database technology background, and system software experience;
- * Develop strong training program for staff, users and management;

- * Agree on standards first before designing a system;
- * Design a total system, but implement it in segments;
- * Experiment with different approaches;
- * Implement a DED/D early;
- * Consider the usage of a DBMS early;
- * Do benchmarks when possible;
- * Don't try to do too much at once;
- * Be patient. It may be a long time before you see results.

5. OBSERVATIONS

In the Federal Government, interest has been increasing both with respect to database administration, and to the two most basic database administration tools, the DBMS, and the DED/D. There is a Federal Information Processing Standards Task Group on Data Base Management System Standards (TG-24), and a Federal Information Processing Standards Task Group on Data Element Dictionaries/ Directories (TG-17).

A recent trend is to utilize existent software tools to perform automatable functions. The software industry has developed new tools and fine-tuned existing ones to the extent that today, there is a proliferation of software tools that can help the DBA. In addition, a number of university projects are focusing on database software tools. The DBA toolchest discussed in this report provides the technical means for implementing a database environment.

All the DBA's interviewed reported that the two software tools they use most are the DBMS and the DED/D. This overwhelming response is expected, since the utilization of these two very basic database administration tools supports an effective, efficient and secure database.

Organizational placement influences the effectiveness of the DBA. The closer the DBA is to executive management, the stronger the influence he can exert on database administration practices in the organization.

Organizations with a long-established DBA function frequently have adopted a "project team" approach, with considerable user involvement.

Organizations that have developed a strong Database Master Plan have a smoother transition into the database environment. Their database functions are better defined, and many of the non-technical problems are more readily resolved.

Expertise in computer technology as well as in database technology, and administrative skills are essential for the DBA and his staff. In addition, the political nature of the position requires diplomatic finesse.

Organizations that have established good public relations within the database administration area have profited from fewer disagreements and confrontations between DBA's, users, staff, and management. When the liaison function is strongly coupled to a good database technology training program for staff, users, and management, fewer non-technical and technical problems arise.

Stage of implementation is a temporary distinction, for, as development progresses, the functional characteristics converge. Thus, it is not surprising that "operational" activities are better organized, have larger staffs, have higher grades, and have better-defined plans than activities in the initiation stages.

It is interesting to note that although the advice offered by practicing DBA's is specifically concerned with database administration, it is remarkably similar to the advice offered to software managers [15].

6. IMPLICATIONS OF DBA COMMITMENT

The decision to implement database administration functions in an organization must be weighed in the context of the organization's needs and resources. Ideally, feasibility studies and cost-benefit analyses should be conducted to determine whether or not to adopt the database approach [13]. If these analyses indicate the establishment of a database administration function, then a good "Database Master Plan" should be prepared, which includes the components of the database environment, the mechanics of implementation, definition of responsibilities and authority, and rules and procedures.

Although the incorporation of database administration concepts does not solve all database problems automatically, a well-implemented DBA function can do much to improve the management and control of an organization's data resources. There are two dimensions to a successful implementation of database administration functions: the advantages to management, and the commitment that management must provide. What database administration should do for management is discussed below. In order to ensure the success of the DBA function, the highest level management must give full support to database administration. A discussion of what management must do for the DBA concludes this report.

6.1 What Database Administration Should Do For Management

Adopting database administration concepts can improve an organization's effectiveness, since a focal point is established for the responsibility, the management, and the control of the total data resources. Some of the advantages to management of having a strong database administration function are detailed below:

- * A controlled database environment can help assure efficient performance and increased operational reliability in the manipulation of data. It can promote data integrity; encourage standard data usages; enforce security safeguards; ensure controlled accessibility; and balance conflicting requirements.
- * Centralization of data resources can result in shared databases, and encourage effective specification and management of the total organizational data resources. Design and development of database application systems can be improved through the use of the DBA software toolchest. Consistent and timely documentation can be enforced through the application of uniform rules and procedures.
- * Uniform database monitoring can facilitate a total organization overview of all data resources. It can help in managing the growth and changes occurring in the databases, by ensuring that the growth is anticipated and controlled. Optimization of database utilization can result from enforced shared data resources. Reorganization, redesign, and restructuring activities can be performed centrally for the entire organization, as these become necessary.
- * Reduced cost of computer operations can result from the elimination of unnecessary duplication in collecting, processing, and disseminating data. Further, timely and

up-to-date reports can help management in making cost-effective decisions.

6.2 What Management MUST Do for the DBA

Once it has been decided to adopt database administration concepts, full commitment and support must be given by the highest level management to the Database Administrator, since the implementation of these concepts affects the entire organization. This commitment and support must be expressed in the form of:

* Authority: The DBA must be given the authority to make decisions and the power to implement any required changes. One of the ways in which this authority could be ensured, is to place the DBA very high organizationally.

* Definition of Responsibilities: The DBA's responsibilities must be clearly defined, preferably in a formal document such as a charter. This is essential if later jurisdictional disputes are to be avoided.

* Compliance Power: The DBA must be given the power to enforce the rules and regulations associated with the implementation of database administration concepts.

* Resources: The DBA must be given the necessary resources to carry out his functions, including staff, time, money, and equipment.

APPENDIX A

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APPENDIX B

DBA INTERVIEW OUTLINE

1. What is the DBA function in your organization called?
2. Where is this function located organizationally?
3. Are there other DBAs not in your group, but in your organization?
4. Is the function project-oriented or overall organization-oriented?
5. Is it primarily administrative or primarily technical?
6. How many people are in the group? Do they work at this task full-time or part-time? Are they technical or administrative types? What specific training in database management do they have?
7. When was this position/function created?
8. What was the purpose in creating it?

TASKS

9. From the attached list of functions performed by DBA's, check those which are performed by your group. (If performed by a different group, indicate this.)
10. Additions to this list?
11. Rank the 3-5 major categories of tasks most often performed.
12. Rank the 3-5 major categories of tasks you deem most important.

TOOLS

13. Describe the hardware/software environment.
14. Check on the list of tools those that are used in data administration, and whether you bought, leased or built them.
15. Is our list of tools complete?

16. Are there other tools you use? (Include non-automated tools.)

17. If more than 1 DBMS is used, are they administered by the same DBA group?

PROBLEMS

18. What non-technical problems did you encounter? (organizational, jurisdictional, resistance...)

19. What technical problems did you encounter? (hardware/software/DBMS incompatibilities, non-availability...)

20. What would you have done differently, given the chance now?

21. Are the 'database commitment' and DBA concept firmly entrenched in your organization?

22. What advice would you offer to a new DBA, based on your experience?

23. Do you know other DBA's in the Government?

APPENDIX C

DATABASE ADMINISTRATION TASKS -- INTERVIEW OUTLINE

DATE: _____
NAME: _____ TITLE: _____
AGENCY: _____

DATABASE ADMINISTRATION TASKS

RESPONSIBILITY OF:
DBA OTHER

1. Database definition / redefinition

- a. defines data elements
- b. defines relationships among elements, programs, reports, etc.
- c. defines data standards

2. Selection / Procurement

- a. hardware
- b. software
- c. services

3. Database design / redesign

- a. structures database (including designs of mapping and search strategies)
- b. designs DED/D
- c. designs database support software

4. Database creation

- a. collects data
- b. implements data definitions
- c. implements the DED/D
- d. implements database support software

5. Integrity/ Security

- a. designs and develops integrity checks to the system (including validation rules)
- b. implements failsafe procedures (backup and recovery)
- c. specifies and implements audit trails and loggings (e.g., recording of the updates and changes to the database)
- d. defines auditing requirements
- e. provides security authorization and assigns passwords

6. Maintenance/ Management

- a. maintains DED/D
- b. updates database definitions
- c. maintains database documentation
- d. develops policies and practices for data usage

7. Performance monitoring and evaluation

- a. reviews and evaluates performance of automated data activities
- b. reviews and evaluates procedural data activities
- c. initiates system improvements (redefinition, restructure database, new procedures, new procurements, etc.)
- d. determines economics of data usage (e.g., assesses impact of changes)
- e. maintains awareness of the state of the art in database technology

8. Enforcement

- a. develops and administers database control procedures
- b. determines compliance with established standard usages
- c. is responsible for access control and security of the database

9. Liaison

- a. with users for assistance and information
- b. with systems and applications analysts/programmers for information, and compliance with standards
- c. with organizational management

10. Training

- a. users
- b. staff
- c. management briefings and seminars

APPENDIX D

DATABASE ADMINISTRATION TOOLS -- INTERVIEW OUTLINE

TOOLS	NAME	USED IN WHICH TASK?
<hr/>		
Data Base Management System (DBMS)		
Data Element Dictionary/Directory (DED/D)		
Information/Data Retrieval Systems		
Online query systems		
Data entry systems		
Editors		
Flowchart generator		
Text processors		
Report generators		
Cross reference generators		
Text/file reformatter		
Data/file maintenance programs		
Data editing and validation systems		
Data auditor		
Data security		
Test data generator		
Optimizers		
Automatic Space generator		
Scheduler		
Project manager		
Librarian (program, file, etc.)		

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS SP 500-28	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE COMPUTER SCIENCE & TECHNOLOGY Database Administration: Concepts, Tools, Experiences, and Problems		5. Publication Date March 1978	
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