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16. Abstract

The rapid proliferation of computerized information systems has created an urgent need for better methods to determine what the contents of the data bases for these systems should be. The central theme underlying the methodology, which is proposed for making this determination, is that there are certain types of information concerning what the contents of a data base should be that can be best provided by the most knowledgeable people in the area, i.e. the potential users of the system. A concurrent consideration, which also makes it highly desirable to have the potential users involved in the development of their system, is that participation in decision making has been shown to lead to greater group acceptance. This aspect of potential user involvement is especially important, since group acceptance is critical to the success of any information system.

A Delphi type methodology provides a means whereby the opinions of the potential users can be effectively integrated in regard to the types of data that are important in a data base. Procedures for implementing the methodology are developed, and a generalized computer program for processing the information flows associated with the method is described. The description of an actual application of the method to the design of the data base for the Pavement Feedback Data System (PFDS), which is currently under development in the Texas Highway Department, is used as an example to illustrate the concepts involved.

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INFLUENCE OF COGNITIVE STYLE IN A METHODOLOGY FOR DATA BASE DESIGN

by

Ronald R. Bush

Research Report Number 123-27

A System Analysis of Pavement Design and Research Implementation

Research Project 1-8-69-123

conducted

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

by the

Highway Design Division
Texas Highway Department

Texas Transportation Institute
Texas A&M University

Center for Highway Research
The University of Texas at Austin

February 1975

The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PREFACE

This report results from research conducted under Research Project No. 1-8-69-123, "A System Analysis of Pavement Design and Research Implementation." The project was initiated in 1969 and is being conducted jointly by the Texas Highway Department, the Center for Highway Research, and the Texas Transportation Institute. The study is part of a cooperative research program with the Department of Transportation Federal Highway Administration.

This study was conducted to obtain the background necessary to establish an automated data feedback system, called the Pavement Feedback Data System (PFDS). This system would be of great benefit in the areas of pavement research, design, and maintenance. The study discussed herein produced a tentative list of items for the PFDS, a rating assigned by the Delphi participants of the importance of each item, and a list of reported redundancies in the set of items. It is felt that this information, which has been made available to the Texas Highway Department, will serve as a basis for the formulation of a definite set of items for inclusion in PFDS.

The author gratefully acknowledges the assistance and encouragement of Dr. Timothy Ruefli. The author also acknowledges the contributions of Drs. Knight, Howard, Hudson, and McCullough.

Mr. Hugh Williamson of the Center for Highway Research proposed the statistical procedure used to test for differences between data base designs. Without his assistance in this area the quality of the study would have suffered significantly.

Mr. James L. Brown of the Texas Highway Department made many valuable suggestions regarding the Delphi procedures. Not only did his recommendations contribute to the effectiveness of the Delphi process in the Highway Department, but many of the procedures he suggested will undoubtedly be incorporated in subsequent applications of the method.

The 241 individuals from the Texas Highway Department, Center for Highway Research, and Texas Transportation Institute, who participated in the PFDS data base design project, each deserve a special word of thanks. Their diligence and dedication made the project a success; and I am proud to have been associated with such an outstanding group.

Ronald R. Bush

February 1975

LIST OF REPORTS

Report No. 123-1, "A Systems Approach Applied to Pavement Design and Research," by W. Ronald Hudson, B. Frank McCullough, F. H. Scrivner, and James L. Brown, describes a long-range comprehensive research program to develop a pavement systems analysis and presents a working systems model for the design of flexible pavements. March 1970

Report No. 123-2, "A Recommended Texas Highway Department Pavement Design System Users Manual," by James L. Brown, Larry J. Buttler, and Hugo E. Orellana, is a manual of instructions to Texas Highway Department personnel for obtaining and processing data for flexible pavement design system. March 1970

Report No. 123-3, "Characterization of the Swelling Clay Parameter Used in the Pavement Design System," by Arthur W. Witt, III, and B. Frank McCullough, describes the results of a study of the swelling clays parameter used in pavement design system. August 1970

Report No. 123-4, "Developing A Pavement Feedback Data System," by R. C. G. Haas, describes the initial planning and development of a pavement feedback data system. February 1971

Report No. 123-5, "A Systems Analysis of Rigid Pavement Design," by Ramesh K. Kher, W. R. Hudson, and B. F. McCullough, describes the development of a working systems model for the design of rigid pavements. November 1970

Report No. 123-6, "Calculation of the Elastic Moduli of a Two Layer Pavement System from Measured Surface Deflections," by F. H. Scrivner, C. H. Michalak, and William M. Moore, describes a computer program which will serve as a subsystem of a future Flexible Pavement System founded on linear elastic theory. March 1971

Report No. 123-6A, "Calculation of the Elastic Moduli of a Two Layer Pavement System from Measured Surface Deflections, Part II," by Frank H. Scrivner, Chester H. Michalak, and William M. Moore, is a supplement to Report No. 123-6 and describes the effect of a change in the specified location of one of the deflection points. December 1971

Report No. 123-7, "Annual Report on Important 1970-71 Pavement Research Needs," by B. Frank McCullough, James L. Brown, W. Ronald Hudson, and F. H. Scrivner, describes a list of priority research items based on findings from use of the pavement design system. April 1971

Report No. 123-8, "A Sensitivity Analysis of Flexible Pavement System FPS2," by Ramesh K. Kher, B. Frank McCullough, and W. Ronald Hudson, describes the overall importance of this system, the relative importance of the variables of the system and recommendations for efficient use of the computer program. August 1971

Report No. 123-9, "Skid Resistance Considerations in the Flexible Pavement Design System," by David C. Steitle and B. Frank McCullough, describes skid resistance consideration in the Flexible Pavement System based on the testing of aggregates in the laboratory to predict field performance and presents a nomograph for the field engineer to use to eliminate aggregates which would not provide adequate skid resistance performance. April 1972

Report No. 123-10, "Flexible Pavement System - Second Generation, Incorporating Fatigue and Stochastic Concepts," by Surendra Prakash Jain, B. Frank McCullough and W. Ronald Hudson, describes the development of new structural design models for the design of flexible pavement which will replace the empirical relationship used at present in flexible pavement systems to simulate the transformation between the input variables and performance of a pavement. January 1972

Report No. 123-11, "Flexible Pavement System Computer Program Documentation," by Dale L. Schafer, provides documentation and an easily updated documentation system for the computer program FPS-9. April 1972

Report No. 123-12, "A Pavement Feedback Data System," by Oren G. Strom, W. Ronald Hudson, and James L. Brown, defines a data system to acquire, store, and analyze performance feedback data from in-service flexible pavements. May 1972

Report No. 123-13, "Benefit Analysis for Pavement Design System," by Frank McFarland, presents a method for relating motorist's costs to the pavement serviceability index and a discussion of several different methods of economic analysis. April 1972

Report No. 123-14, "Prediction of Low-Temperature and Thermal-Fatigue Cracking in Flexible Pavements," by Mohamed Y. Shahin and B. Frank McCullough, describes a design system for predicting temperature cracking in asphalt concrete surfaces. August 1972

Report No. 123-15, "FPS-11 Flexible Pavement System Computer Program Documentation," by Hugo E. Orellana, gives the documentation of the computer program FPS-11, October 1972. April 1972

Report No. 123-16, "Fatigue and Stress Analysis Concepts for Modifying the Rigid Pavement Design System," by Piti Yimprasett and B. Frank McCullough, describes the fatigue of concrete and stress analyses of rigid pavement. October 1972

Report No. 123-17, "The Optimization of a Flexible Pavement System Using Linear Elasticity," by Danny Y. Lu, Chia Shun Shih, and Frank H. Scrivner, describes the integration of the current Flexible Pavement System computer program and Shell Oil Company's program BISTRO, for elastic layered systems, with special emphasis on economy of computation and evaluation of structural feasibility of materials. March 1973

Report No. 123-18, "Probabilistic Design Concepts Applied to Flexible Pavement System Design," by Michael I. Darter and W. Ronald Hudson, describes the development and implementation of the probabilistic design approach and its incorporation into the Texas flexible pavement design system for new construction and asphalt concrete overlay. May 1973

Report No. 123-19, "The Use of Condition Surveys, Profile Studies, and Maintenance Studies in Relating Pavement Distress to Pavement Performance," by Robert P. Smith and B. Frank McCullough, introduces the area of relating pavement distress to pavement performance, presents work accomplished in this area and gives recommendations for future research, August 1973.

Report No. 123-20, "Implementation of a Complex Research Development of Flexible Pavement Design System into Texas Highway Department Design Operations," by Larry Buttler and Hugo Orellana, describes the step by step process used in incorporating the implementation research into the actual working operation.

Report No. 123-21, "Rigid Pavement Design System, Input Guide for Program RPS2 in Use by the Texas Highway Department," by Robert F. Carmichael and B. Frank McCullough, describes the input of variables necessary to use in the Texas rigid pavement design system program RPS2, May 1974.

Report No. 123-22, "An Integrated Pavement Design Processor," by Danny Y. Lu, Chia Shun Shih, Frank H. Scrivner and Robert L. Lytton, provides a comprehensive decision framework with a capacity to drive different pavement design programs at the user's command through interactive queries between the computer and the design engineer.

Report No. 123-23, "Stochastic Design Parameters and Lack-of-Fit of Performance Model in the Texas Flexible Pavement Design System," by Malvin Holsen and W. Ronald Hudson, describes a study of initial serviceability index of flexible pavements and a method for quantifying lack-of-fit of the performance equation.

Report No. 123-24, "The Effect of Varying the Modulus and Thickness of Asphaltic Concrete Surfacing Materials," by Danny Y. Lu and Frank H. Scrivner, investigates the effect on the principal stresses and strains in asphaltic concrete resulting from varying the thickness and modulus of that material when used as the surfacing of a typical flexible pavement (being prepared for submission).

Report No. 123-25, "Elastic Layer Theory as a Model of Displacements Measured Within Flexible Pavement Structures Loaded by the Dynaflect," by Frank H. Scrivner et al, describes the fitting of an empirical model to the study of 136 (TTI) data (being prepared for submission).

Report No. 123-26, "Modification and Implementation of the Rigid Pavement Design System," by Robert F. Carmichael and B. Frank McCullough, describes the new RPS-3 version of the rigid pavement design system in detail and complete with an input guide, documentation, and listing.

Report No. 123-27, "Influence of Cognitive Style in a Methodology for Data Base Design," by Ronald R. Bush, includes a treatment of the Delphi process applied to the design of the Pavement Feedback Data System.

ABSTRACT

The rapid proliferation of computerized information systems has created an urgent need for better methods to determine what the contents of the data bases for these systems should be. The central theme underlying the methodology, which is proposed for making this determination, is that there are certain types of information concerning what the contents of a data base should be that can be best provided by the most knowledgeable people in the area, i.e. the potential users of the system. A concurrent consideration, which also makes it highly desirable to have the potential users involved in the development of their system, is that participation in decision making has been shown to lead to greater group acceptance. This aspect of potential user involvement is especially important, since group acceptance is critical to the success of any information system.

A Delphi type methodology provides a means whereby the opinions of the potential users can be effectively integrated in regard to the types of data that are important in a data base. Procedures for implementing the methodology are developed, and a generalized computer program for processing the information flows associated with the method is described. The description of an actual application of the method to the design of the data base for the Pavement Feedback Data System (PFDS), which is currently under development in the Texas Highway Department, is used as an example to illustrate the concepts involved.

The Delphi process also provides an effective research methodology for investigating the effects that certain personal characteristics of the potential users have on the data base designs achieved. The cognitive styles of the Delphi participants in the PFDS study were assessed along the field-dependent/independent dimension as measured by the Hidden Figures Test. Then the influence of cognitive style on the data base designs achieved by different Delphi groups was investigated. It was concluded that Delphi groups, composed of participants with different cognitive styles, converge to data base designs that are significantly different from one another.

The effect of Delphi participation on the attitudes of the potential users toward the system was also investigated in the PFDS study. A small but statistically significant, overall positive change in attitude was observed after the potential users had participated in the data base design process.

The successful application of a Delphi type methodology to the design of the PFDS data base has proven that the process provides a viable method for involving the potential users in the design of their system. Furthermore, it is concluded that the method possesses excellent potential for widespread application in the area of data base design.

KEY WORDS: Delphi process, Pavement Feedback Data System (PFDS), cognitive style.

SUMMARY

It has become evident in dealing with the decisions faced by pavement engineers that a vast amount of past experience exists which, if available, would be of great benefit. Perhaps the most practical method of making such information readily available is through the means of a computerized data base.

By capturing and storing data from in-service pavements as well as on new construction, an inventory of the Texas pavement network can be established in the form of a computerized data base resident on the Texas Highway Department (THD) System 370 in Austin. This Pavement Feedback Data System (PFDS) can then be used for research, design, and management functions. It is intended that this information will supplement the pavement engineer's judgment and assist him in making better pavement decisions.

In determining what information should be stored in PFDS, care must be exercised so that all necessary information will be available when needed, while other items should be excluded from the system as their presence would only increase the operating costs. The potential users of the system, who also tend to be the most knowledgeable people in the area of pavement-related problems, are best suited for providing the contents of the PFDS data base. However, it is difficult for a large group of people to agree on something as involved as the set of items to be stored on a computerized information system. Thus, the Delphi process is used whereby each individual makes his contributions free from the psychological forces of the group. By a process of iterations, in which each person reconsiders his judgment in light of the group consensus from the previous iteration, the individuals of the group begin to converge in their ideas. Thus, the items to be contained in the data base are obtained.

The Delphi process was used in this study to generate a proposed list of items for inclusion in a Texas Pavement Feedback Data System. The list, together with accompanying information including importance ratings assigned to all the items by the Delphi participants, is presented in this report. The

list is possibly the most important practical result of this study, since it relates directly to the implementation of PFDS.

A discussion is also given on the relationship between the cognitive style of the participants and their preferences about the composition of the data base. The participants were ranked on a global-analytical cognitive style continuum by means of certain testing procedures applied before the Delphi experiment. The following specific results were obtained:

(1) The number of data items initially submitted by the participants is correlated with their cognitive styles.

(2) Homogeneous Delphi groups, composed of participants with different cognitive styles, converged to data base designs that were significantly different from each other.

(3) The manner in which the Delphi groups are structured, relative to cognitive style, appears to be an important consideration not only in regard to the data base design achieved, but also in regard to the degree to which the subjects are able to participate effectively in the process. The global type of individual appears to function better in a group composed solely of other global types.

Finally, an improvement in the attitude of the participants toward the data base was achieved by their taking part in the Delphi process. The improvement was small, but statistically significant at the .05 level.

IMPLEMENTATION STATEMENT

This study has yielded a tentative set of items for inclusion in PFDS, a list of items in the set which appear to be redundant, and an importance rating assigned to each item. This information provides the basis for the formulation of a definite set of data items for inclusion in the preliminary PFDS. The list and importance ratings are especially useful since they were obtained from potential users of the data base within the Texas Highway Department and supporting research institutions and thus reflect the interest and knowledge of field personnel.

Recommendations for use of the proposed set of data items in designing PFDS are given below following a brief summary of necessary background information which is discussed in detail in the report.

For the purposes of studying the effect of certain personality factors on the preferences about PFDS data items, the participants were classified into five categories on the basis of initial testing. Differences between people who tend to think in analytical and those who think in broad or global terms were investigated. Additionally, those with an initial low attitude about the data base were studied separately.

The participants were divided into 21 separate groups, including four replicate groups within each of four personality classifications, four control groups, and a late entry group. Each of the 21 groups selected its own proposed list of items for PFDS by the Delphi process, which is discussed in the body of this report. Thus, the initial outcome of the experiment was 21 separate proposed lists of items.

All of the items included by any of the groups are listed in Appendix F along with the average importance rating assigned to each item by the groups which included the item. The additional information provided in the appendix for each item is as follows:

(1) the number of groups out of 21 which included the item,

(2) the lowest and highest of the importance ratings assigned to the item by the groups that included it, and

(3) additional information indicating which specific groups included the item.

Two steps are now needed to produce a definite set of items for inclusion in the preliminary PFDS: elimination of redundancies in the list and selection of the items from the resulting duplication-free list for actual inclusion.

The elimination of redundancies will be greatly facilitated by the list of duplications reported during the experiment by the participants. This list is also given in Appendix F. Further examination will be required, however, to eliminate all redundancies and choose the best of each set of alternate terms.

The selection of the items from the duplication-free list for actual inclusion will be aided considerably by the importance ratings assigned all proposed items by the participants in the study. The importance ratings have the following verbal meanings:

5.0 Imperative that item be included

4.0 Highly important

3.0 Moderately important

2.0 Of questionable importance

1.0 Low importance

0.0 Absolutely no importance.

Clearly, any scheme for selecting part of the list of proposed items will involve some subjectivity, but the importance ratings provide a basis for a systematic approach. The following are recommendations for such an approach.

First, it is suggested that items with average importance ratings of 3.0 or higher be included, whereas all items with a value of 2.0 or lower be excluded from the final list. Any item given at least one rating of 4.0 or higher should probably be included, since at least one of the 21 groups considers that item to be highly important. For marginal items, it is suggested that both the number of groups that included the item and the range of importance ratings be considered. A large range indicates a substantial diversity in feeling toward an item; if there are a few high ratings, inclusion may be warranted, even though the average is low.

TABLE OF CONTENTS

APPENDICES

CHAPTER 1. INTRODUCTION

The last few years have witnessed the rapid beginning of what is predicted to be a major movement toward the installation of computerized data base systems in organizations. This movement has been and is being fueled by our continuing progress in computer technology. If the expected progress in the areas of low-cost, high-capacity, random access devices and storage management techniques materializes, the growth in the installation rate of data base systems may well be explosive. Unfortunately, this rapid technological progress in our ability to install data base systems has been outstripping our understanding of what the data contents of these systems should be. Therefore, the research effort described in this report was undertaken with the objective of developing and refining a data base design methodology that will help to close the heretofore growing gap between our technological capability and our ability to design data base systems that contain data which will effectively aid management decision making.

The Need for Data Base Design Techniques

Jerome Kanter (Ref 51, p 213) discusses the results of a study, to evaluate the relative importance of potential MIS research projects, that was conducted by the Society for Management Information Systems during its founding conference in 1969. The conference was attended by 125 individuals who represented a wide cross section of highly experienced MIS professionals. These individuals were asked to rank twenty-six potential MIS research projects in relation to their perceived importance, and a composite ranking of the group's opinion was then developed. The three most highly ranked projects in the order of their relative importance were:

(1) development of methods for determining what the content of an information system should be,

(2) investigation into the characteristics of decision makers which affects MIS system design, and

(3) investigation of means for overcoming user-designer interface problems. (Ref 51, p 216)

Since it is difficult to imagine how any one of the three top ranked projects could be successfully completed without giving at least partial attention to the other two, this author views the considerations embedded in the projects as being inseparable. Therefore, it was deemed essential that both the data base design methodology and the experimental design, described in this report, address all three of the above considerations.

Further and more recent evidence of the pressing need for better data base design techniques can be found in "A Study of Critical Factors in Management Information Systems for U.S. Air Force" (Ref 12) that was conducted in 1973 at Colorado State University. In this study, personnel from a widely diversified sample of business organizations and government agencies were interviewed with the objective of determining what factors are most critical in information systems design. In the list of twenty critical factors that was developed, "identification of information needs of management" was ranked second, just barely behind the first ranked factor which was "definition of objectives of the system" (Ref 12, p 9).

There is little doubt that one of the foremost problems facing the information systems designer today is how to determine what the content of an information system should be. This report examines a Delphi methodology for data base design that appears to offer great potential for overcoming this problem.

The Delphi Technique

The "Delphi Technique," an ongoing project of the Rand Corporation which was begun shortly after World War II, is a method for achieving a reasoned consensus of opinion among a group of experts. The purpose of the method is to avoid the direct confrontation of the experts by means of an iterative interrogation scheme in which only the administrator is aware of the sources of information which is fed back to the participants. A concise but detailed description of the technique is given by Helmer who was one of the many contributors to the method.

> The "Delphi Technique," eliminates committee activity, thus further reducing the influence of certain psychological factors, such as

> specious persuasion, the unwillingness to abandon publicly expressed opinions, and the bandwagon effect of majority opinion. This technique replaces direct debate by a carefully designed program of sequential individual interrogations (best conducted by questionnaires) interspersed with information and opinion feedback derived by computed consensus from the earlier parts of the program. Some of the questions directed to the respondents may, for instance, inquire into the "reasons" for previously expressed opinions, and a collection of such reasons may then be presented to each respondent in the group, together with an invitation to reconsider and possibly revise his earlier estimates. Both the inquiry into the reasons and subsequent feedback of the reasons adduced by others may serve to stimulate the experts into taking into due account considerations they might through inadvertence have neglected, and to give due weight to factors they were inclined to dismiss as unimportant on first thought (Ref 44, p 47).

Decision making within organizations quite frequently requires the type of expert opinion that the Delphi method has proven to be helpful in eliciting. Helmer and Rescher point out that even "in certain engineering applications, particularly of relatively underdeveloped branches of physics, the reliance upon 'know-how' and expert judgment is just as pronounced as it is in the applications of political science to foreign-policy formation." An example of this phenomena is readily apparent in the design and management of highway pavement systems where stochastic variations necessitate the reliance on professional experts to "supplement the various explicit elements by appropriate use of their capacities for an intuitive appraisal of the many intangible factors which critically affect the final outcome" (Ref 44, pp 40-41).

An idea which is widespread today is that this type of decision making can be aided by appropriately designed information systems. However, when dealing with complex problems, such as pavement management where stochastic variation in the decision variables is prevalent, the determination of what is relevant data to include in a data base is not always clear. In fact the uncertainty, in what to include, creates a substantial danger because of the large capital outlay that is required to bring an MIS into existence. On the other hand it is this same uncertainty in the decision variables that creates the greatest opportunity for the use of an MIS. If a problem is clear cut, well defined, and has explicit decision variables, then there is little need for a data base type of information system. Danger and opportunity appear as opposite sides of the same coin when considering an MIS. A method is needed for the design of data bases that is more certain than flipping a coin that may even be loaded in favor of the danger side.

If data based information systems are to prove successful in supplying information that will aid management in making and implementing decisions, then the design of the data structures of these data bases will have to either complement or incorporate the "know-how" and expert judgment of the present decision makers, who are also the potential users of the system. Theoretically no one should be more capable of describing the necessary data content of these data bases than the present decision makers themselves, and the Delphi Technique offers a method for bringing about a convergence of this expert opinion.

Not only is an advantage gained by bringing the expertise of the most knowledgeable people to bear on the problem, but also an additional organizational behavior advantage can be expected to accrue from the application of a Delphi type methodology to the design of a data base. This additional advantage occurs because the potential users of the system are allowed to directly participate in its development. Group acceptance of an information system is critical to its effectiveness. Unless an information system is used, there is no way to justify the cost required to bring it into existence. By participating in the development of the system, the group's attitude toward the system is likely to improve and the probability of the system being used is, therefore, greatly increased. One of the objectives of the research effort described in this report was to verify this expected improvement in attitude as a result of participation in a Delphi design of a data base.

The Delphi Technique, which receives its name from the oracle at Delphi in ancient Greece, has since its inception been used by industry and governmental agencies to forecast future technological developments. This future aspect of Delphi is felt by the author to hold a significant connotation for the application of the technique to the area of data base design. A data base requires a certain amount of time for development to the operational stage after its design has been finalized. Even after the data base is operational, the information system is commonly used to assist with decisions that are made possibly years after the system has reached the operational stage. Thus the people who participate in the design of a data base are in actuality attempting to predict what types of data are likely to be needed in future decision making. The Delphi Technique provides a proven vehicle for delving into this type of uncertain and opinion laden question.

This report will in part describe the development of a Delphi methodology for data base design that provides a user-designer interface through which a determination can be made as to what the content of an information system should be. Consideration will thus be given to the first and third highest ranked projects in the Society for Management Information Systems' list of potential MIS research projects.

Cognitive Style

The second highest ranked project in the list of potential MIS research projects is concerned with the characteristics of decision makers which affect MIS system design. Cognitive style, a personal characteristic of decision makers, is a stable individual preference for a particular "mode of perceptual organization and conceptual categorization of the external environment. One particular style dimension involves the tendency to analyze and to differentiate the stimulus environment in contrast to categorizations that are based on the stimulus as a whole." Some people "characteristically analyze and differentiate the stimulus field, applying labels to subelements of the whole. Others tend to categorize a relatively undifferentiated stimulus." Some people "are splitters, others are lumpers" (Ref 92, p 74).

It should be recognized that the splitting and lumping labels define "ideal" types of behavior that represent the end points of a continuum. In reality we find individuals widely distributed along the continuum; however, throughout this report we will define the individual who tends to lie relatively closer to the splitting end of the continuum as having an analytical cognitive style while defining the individual who lies closer to the lumping end of the continuum as having a global cognitive style.

The characteristic mode of cognitive functioning, with which the individual approaches most of his perceptual and intellectual tasks, is believed to be a combined product of experience and educational background. Thus, the particular cognitive style of an individual is solidified over a long period of time and is very difficult if not impossible to alter in anything less than months of concentrated effort. "Individuals tend to develop in a direction that is suited to some problem-types and less effective with others. Mature and competent adults generally have an accurate sense of which situations to seek out and which to avoid. A particular cognitive style is neither good nor bad; its effectiveness depends on the context within which the person acts" (Ref 54, p 1).

Some implications of the cognitive style factor for information system designers can be found in the results of recent research. Huysmans tested the impact of cognitive style differences between the operations researcher and the manager on the managerial implementation of operations research recommendations, and he concluded that the cognitive style of the intended user can operate as an effective constraint on the implementation of operations research recommendations (Ref 46). Doktor and Hamilton extended the work of Huysmans by investigating "the extent to which cognitive style differences, as measured by written tests of perceptual functioning, account for differential acceptance rates of written reports with contrasting presentation styles." They found that different reporting styles have different acceptance rates by individuals who possess a global or analytical style. They claim that their results "highlight the potential influence and importance of increased understanding of differential thought processes in management science implementation" (Ref 27).

Mason and Mitroff in outlining "A Program for Research on Management Information Systems" identify the psychological type of the decision maker as one of the key variables that comprise an MIS. They discuss a personality typology that is similar to the cognitive style types alluded to in this report, and they state that "what is information for one type will definitely not be information for another." They have commented that science has tended to be a predominantly analytical activity. "The result is that the design of MIS has tended to reflect this orientation of their designers, i.e., the designers of MIS have tended to project (or mistake) their dominant psychological type (analytical) onto that of their clients. The consequence has been the almost total neglect of MIS designed expressly for the global type."[1] Mason and Mitroff state that "there is a need for more research on this important MIS variable" (Ref 63, pp. 478-479).

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[1]Mason and Mitroff call the analytical type a Thinking-Sensation type and the global type a Feeling-Intuition type. This writer has replaced Thinking-Sensation in the quote with analytical and Feeling-Intuition with global in order to be consistent with preceding portions of this report.

The statement, that what is information for one type will definitely not be information for another, raises some questions concerning the application of a Delphi type methodology to the problem of data base design. Will the number of data items, submitted by potential users for inclusion in a data base, be a function of their particular cognitive style? Will a Delphi group composed solely of potential users who have a particular cognitive style converge to a data base design that is significantly different from that obtained with a Delphi group composed solely of potential users with a different cognitive style? Is the manner in which Delphi groups are structured, relative to cognitive style, likely to have an influence on the data base design achieved? Answers to these questions was one of the primary objectives of the research effort that was carried out in the context of actually applying a Delphi type methodology to the design of a highly complex, real life data base.

Pavement Feedback Data System (PFDS)

Pavement Feedback Data System (PFDS) is an application of the concepts and principles of MIS to the management of the highway pavement system in the state of Texas. "In a sentence, a PFDS is an automated system containing select feedback data from actual in-service highway pavements, to be used for research, design, and management functions" (Ref 83, p 6). The idea behind PFDS is to supplement the pavement decision maker's judgment by providing him with the best possible information regarding the pavement with which he is working.

By capturing and storing data from in-service pavements as well as on new construction, an inventory of the Texas pavement network can be established in the form of a computerized data base resident on the Texas Highway Department (THD) System 370 in Austin. Using the remote terminals located in the District offices throughout the state, this information can be fed back to District personnel either in the form of periodic and event triggered reports or on demand from a query instigated at the District level. It is intended that this information will supplement the pavement engineer's judgment and assist him in making better pavement decisions. Data from the improved pavements will be captured on a continuing basis and an iterative feedback loop established which will eventually result in a substantial improvement in the Texas highway network. Figure 1 illustrates the scope and basic characteristics of the PFDS concept (Ref 83, p 4). The question is what data should be captured and stored in the data base.

Although the cornerstone of a Delphi type methodology for data base design is the fact that the potential users of the system determine the contents of the data base, it is still possible to establish a priori gross categories of data for the purpose of illustrating the scope of the system. Four major categories, together with their sub-categories, can be identified:

I. Locational Data

II. Design and Construction Data
   - Maintenance Data

III. Input to the Pavement
   - Traffic Loading
   - Climatic Input

IV. Performance Data

It is necessary to be able to accurately locate a particular point of interest on the highway network and the locational data serves this purpose. The design and construction data along with its sub-category of maintenance data specifies the state of the pavement as it was built and has been maintained. The input to the pavement, which consists of traffic loading and climatic input then affects the manner in which the pavement deteriorates over time. The foregoing variables go together to determine the riding quality of the pavement, and performance data provides measures of this variable. Figure 2 illustrates the interrelationship of the components that make up the pavement management problem (Ref 83, p 28).

In essence the end purpose of PFDS is to assist the pavement engineer in predicting and managing pavement quality when faced with an exceedingly large number of combinations of pavement variables. It is anticipated that this purpose will be accomplished in two ways: (1) by immediately supplementing the judgment of the potential users in the field with accurate data, and (2) by providing data on in-service pavements for on-going research on pavement problems. The first use of PFDS parallels the traditional MIS

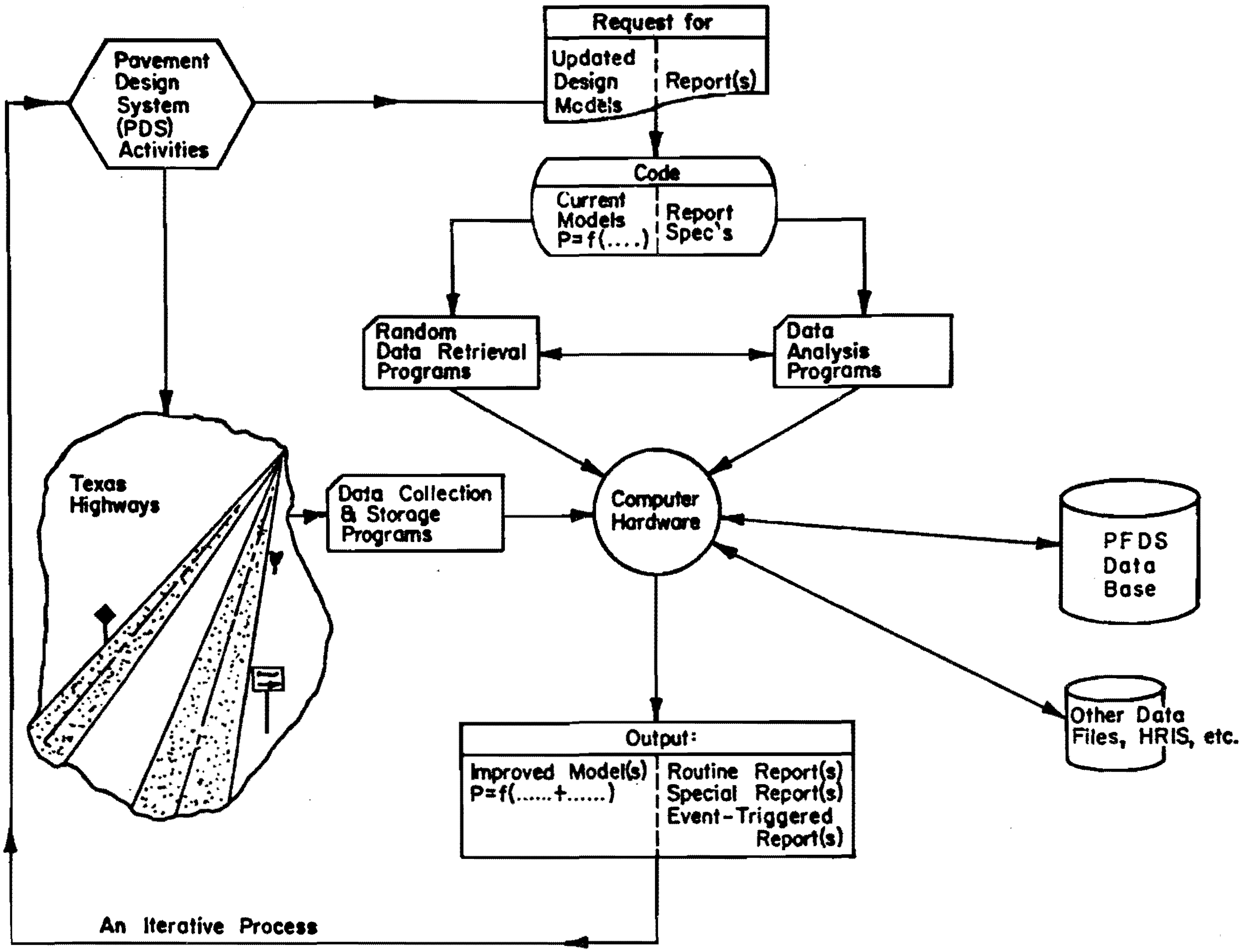

Fig 1. Scope of a pavement feedback data system (PFDS) (after Strom et al, Ref 83).

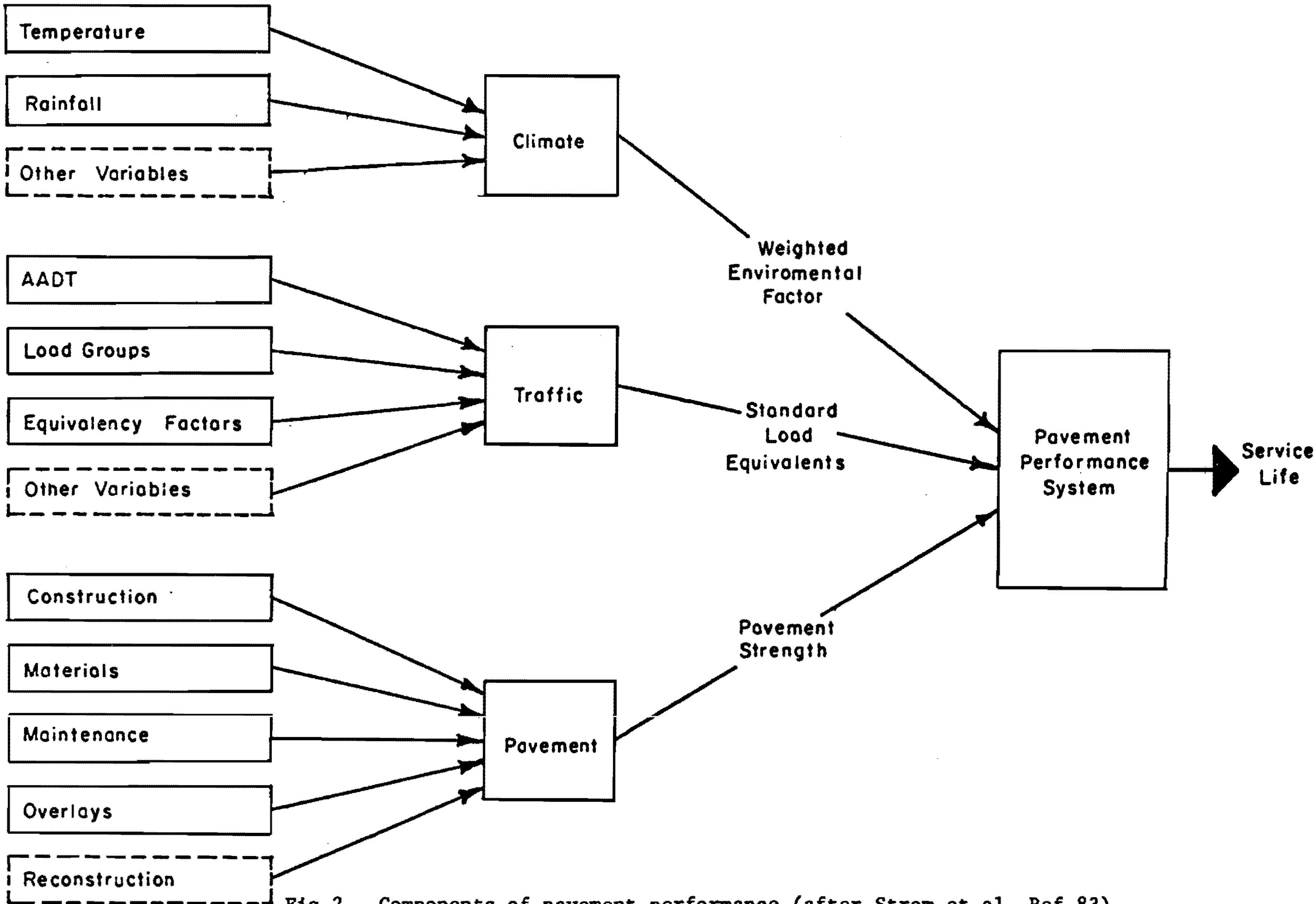

Fig 2. Components of pavement performance (after Strom et al, Ref 83).

approach, while the second use of PFDS is analogous to using the highway system as a research laboratory. With such a laboratory available, more precise identification and quantification of the interrelationships among pavement variables is probable, and this added knowledge should fuel the development of more refined computer models for pavement analysis. Thus PFDS is envisioned as having more than one type of user and more than one function.

It is intended that, when operational, PFDS will be used by three distinct groups within the THD, each of which "will have a different type of information need:

(1) the District Engineer and his staff,
(2) the administrative headquarters and divisions, and
(3) researchers" (Ref 83, p 85).

Within the above mentioned research category, it is anticipated that PFDS will also be used by the THD's two cooperating research institutions, Texas Transportation Institute (TTI) and Center for Highway Research (CFHR). In addition to being accessed and updated by a diverse group of users, it is expected that PFDS will provide information for use in several functional areas, such as:

(1) Design
(2) Maintenance
(3) Administration, and
(4) Research.

In this respect the PFDS data base is viewed as being a truly "common" data base, and it is felt that the Delphi methodology proposed herein offers a means for overcoming some of the many problems inherent in designing a common data base in a complex situation such as PFDS.

One of the potential problems an information systems' designer faces in attempting to develop a common data base like PFDS is the possibility of overlooking the information needs of an important segment of the potential users or even worse missing the real needs of the entire group. A Delphi type methodology requires the involvement of the potential users of the system, and assurance is thus obtained that their needs have been considered.

Examinations of the efforts of two other states in developing information systems similar to PFDS, reveal other advantages for the application of the Delphi technique to the design of the PFDS data base.

> The Wisconsin Department of Transportation designed and built their Highway Network Data and Information (HNDI) System largely independent of a specific group of users. When the system became operational, they found that no user really existed and that the next necessary step was thorough indoctrination of field personnel as to the scope, character, and possible users of HNDI (Ref 83, p 8).

Identification of potential users and their indoctrination as to the scope and character of the system are integral steps in the Delphi process of data base design. Therefore, the problems faced by Wisconsin in attempting to implement HNDI are automatically eliminated by use of the Delphi technique. In addition, the participants in the Delphi process receive valuable training that is expected to facilitate their use of the system when it reaches the operational stage.

Miller and Barrett while describing the implementation of the Florida Department of Transportation's (FDOT) Multiproject Scheduling System (MPSS) caution that it is important to avoid "the appearance of something new being 'rammed down the throats' of the users." They state that

> Quite the opposite feelings can be evoked by bringing the users on board and giving them a strong voice in the system design process. This is one area where the FDOT's design procedure could have been improved. Some complaints of MPSS system users were centered around the fact that the MPSS did not adequately fill their needs and it was something being forced upon them which they had no control over. This implies a certain amount of resentment due to non-participation in the planning process (Ref 69, p 19).

Even though Miller and Barrett have failed to provide explicit instructions for a method that allows the participation they advocate, it is felt that the Delphi methodology employed in the design of the PFDS data base adequately accomplishes the spirit of their proposal. By having 241 potential users from the THD, TTI, and CFHR take part in the Delphi project to design the PFDS data base, it is anticipated that the FDOT's difficulties with implementation problems due to non-participation will be avoided. As was previously mentioned, a further check on the Miller-Barrett proposal was provided since one of the objectives of the PFDS design project was to determine how the attitude of the potential users changed as a result of participating in the data base design process.

Rationale and Limitations

Heretofore, the data content of data bases has generally been determined by the systems analyst who has traditionally employed a variety of techniques in arriving at *his* appraisal of what data items the data base should contain. These techniques include, among others, interviews with the potential users, decision level analysis, information flow analysis, and input/output analysis. The specific technique or combination of techniques that the analyst applies in any given situation is normally dependent upon the analyst's judgment and personal preferences. Thus, up until now, there has been a notable lack of systematic procedures for determining what the content of a data base should be; and this lack has created the potential for some serious problems resulting from the possibility of analyst bias.

By applying the systematic Delphi procedures, the opportunity for the encroachment of analyst bias into the data base design is eliminated. In place of this bias, the Delphi process provides a forum for the expression of many seperate views regarding the data requirements. These views are provided by the different disciplines that are brought to bear on each data item. For example, in the design of the PFDS data base the separate functions of Design, Maintenance, Research, etc. all provided different prespectives in the consideration of each data item. It is through the many separate views which Delphi brings to the problem that the validity of the data content is guaranteed. The validity of the data content is guaranteed either through the agreement of the potential users or through the debate that takes place when the potential users are initially in disagreement. The first type of guarantor is known as a *Kantian Inquiring System* and the second type is known as a *Hegelian Inquiring System* (Ref 63, pp 481-482). Both types of guarantors are well suited for ill-structured problems; and as we have previously seen, most data base systems are designed to cope with problems of an ill-structured nature.

A data base, in order to be effectively utilized, has to fit or match the separate world views held by each of its users. The Delphi process ideally provides the interaction that is necessary to bring about the required synthesis of the separate perceptions held by each of the potential users. A priori it is better that this synthesis be achieved before the system is operational. Thus, theoretically, the Delphi process practically guarantees a better data base design than could be achieved by a systems analyst. Furthermore, the Delphi process appears to be suitable to a wide range of data base design situations.

Although Delphi appears to be applicable to a wide range of data base design situations, there are probably limits as to how deeply involved the potential users can be expected to become in the design process. It is theorized that the degree of successful involvement is dependent on the amount of education and experience the potential users have had with data base systems prior to the design of the data base in question. After the establishment of the objectives to be met by a new system, the steps in designing the data base are roughly: (1) identification of information needs and determination of how the information is to be collected, and (2) classification of data items and development of the data structure. Step 1 could be considered to be of a non-technical nature, in terms of the potential user's view of the data base design process, while Step 2 could be considered more of a technical nature. It is expected that Step 1 can be easily completed by the potential users; however, Step 2 may offer more difficulty unless the potential users have been previously acquainted with data base concepts. For example, in the PFDS data base design project, which will be described in subsequent chapters, the potential users were not previously familiar with data base design concepts; and trial efforts to solicit their help in one area of Step 2 proved to be futile. Until further research can be conducted with potential users who have had some previous experience with data bases, it should be conservatively assumed that the Delphi methodology is limited to the non-technical portion of the data base design process. Verification of Delphi's potential in the non-technical area of data base design was one of the research objectives of the study that will be described in subsequent chapters.

Summary of Research Objectives

Since the research effort described in this report covers several specific objectives within the context of one experimental design, the following summary of the research objectives is included for the convenience of the reader:

(1) To verify the applicability of a Delphi type methodology to the problem of data base design by utilizing the method to determine what the contents of the PFDS data base should be;

(2) To determine what influence, if any, cognitive style is likely to have in a Delphi type methodology for data base design; and in particular to determine:

(a) if the initial number of data items submitted by potential users is a function of their cognitive style,

(b) if a Delphi group composed solely of participants with one cognitive style will converge to a data base design different from that of a Delphi group with participants who have a different cognitive style, and

(c) if the manner in which Delphi groups are structured, relative to cognitive style, is likely to have an influence on the data base design achieved; and

(3) To verify the theoretical assumption that the attitude of the participants toward the system will improve as a result of their participation in the data base design process.

Scope of the Report

This report describes a research investigation conducted to determine the influence of cognitive style in a Delphi methodology as it was applied to the design of the PFDS data base. Theoretically the Delphi technique holds great promise for overcoming some common problems faced by the information system designer. By providing a suitable user-designer interface the method allows the potential users to determine what the contents of their data base should be. In addition, participation in the development of the system is expected to bring about an improved attitude on the part of the users toward the system. Verification of this potential, when the method is actually applied in the context of designing a complex, real-life data base was one of the primary objectives of the research effort that is reported in the following chapters.

Chapter 2 presents a review of the literature, on the Delphi and cognitive style concepts, that is pertinent to the application of these concepts to the area of data base design.

Chapter 3 discusses the modifications to Delphi that are required in order to apply the method to the area of data base design. The PFDS example is used to demonstrate the methodology, and a computer program for processing the Delphi information flows associated with a data base design effort is described.

Chapter 4 presents the hypotheses of the study concerning cognitive style and participation. The chapter then describes the experimental design which was used as a means of gathering the data to test these hypotheses.

Chapter 5 discusses the criteria used in selecting the measurement instrument for numerically assessing the cognitive style of the participants, and it describes the modification of an attitude scale that was used to measure the participants' attitudes toward the system.

Chapter 6 analyzes the relationship that was discovered between the participants' cognitive styles and their ability to articulate data items.

Chapter 7 presents a statistical method for testing the hypothesis that Delphi groups composed of members with different cognitive styles will converge to different data base designs. The results obtained from applying this test to the data gathered in the PFDS project are discussed.

Chapter 8 reports the investigator's subjective opinions, impressions, and observations of the Delphi process; and qualitative differences, between the data base designs of different cognitive style groups, that were observed in the PFDS project are discussed.

Chapter 9 examines the effect that participation in the PFDS data base design process had on the attitude of the participants toward the system and their participation in its development.

Chapter 10 presents the conclusions of the study along with recommendations as to methods for applying the Delphi technique to the area of data base design. Concomittantly recommendations are presented concerning further research that would be beneficial in gaining additional understanding of the methodology.

CHAPTER 2. REVIEW OF THE LITERATURE

In this chapter a review of the literature on the Delphi Technique and Cognitive Style will be undertaken. In this review a brief history, tracing the evolution of the two concepts, will be presented, even though an attempt will be made to concentrate primarily on those aspects of the two concepts that are pertinent to the use of the Delphi Technique as a method for data base design. The procedures that are normally followed in administering the Delphi Technique will be reported in order to obtain a clearer understanding of what, if anything, is likely to be sacrificed by modifying the technique for use as a user-designer interface to determine what the contents of a data base should be. The cognitive style concept is relatively new and as such is not yet completely encompassed within one unifying theory. There are many diverse dimensions to the concept, and this literature review will examine some of these dimensions in order to provide a foundation for the selection of a dimension that is relevant to the task of data base design.

Delphi

"Project Delphi" is an intermittent but ongoing effort of the Rand Corporation which is "concerned with the problem of using group information more effectively. The early studies were concerned mainly with improving the statistical treatment of individual opinions. . . . In 1953, Dalkey and Helmer introduced an additional feature, namely iteration with controlled feedback. The set of procedures that have evolved from this work has received the name *Delphi*" (Ref 19, p 20). "Its object is to obtain the most reliable consensus of opinion of a group of experts. It attempts to achieve this by a series of intensive questionnaires interspersed with controlled opinion feedback." The technique "involves the repeated individual questioning of the experts (by interview or questionnaire) and avoids direct confrontation of the experts with one another" (Ref 22, p 458).

By obviating the necessity for face-to-face discussion, which is the traditional way of pooling individual opinions, Delphi is able to circumvent some serious difficulties that are inherent in face-to-face interaction such as committee meetings. The most serious of these difficulties probably include:

(1) The spurious influence of a high status individual on the group--here the status of an individual, which is often unrelated to his expertise on the question at hand, is given undue consideration in a face-to-face discussion.

(2) Ego commitment--after openly committing himself to a particular position, the individual is less likely to respond to facts and opinions advanced by other members of a face-to-face discussion group.

(3) Group pressure for conformity--in a face-to-face situation the individual encounters great pressure to jump on the bandwagon and join the group.

Delphi's elimination of the disadvantages inherent in a face-to-face encounter allows a group to reach a less emotional and more reasoned consensus of opinion.

It is presently standard procedure to have one or two systems analysts develop a data base design; and this tradition, of avoiding the direct involvement of a large number of the potential users probably stems in part from the problems inherent in face-to-face encounter. Delphi offers a means of avoiding the problems associated with face-to-face encounter, but the primary question is can anything be gained by bringing more people into the process. Dalkey indicates that the answer should probably be in the affirmative. He postulates what he calls the "n-heads rule," i.e. n heads are better than one. He states

> The basis for the n-heads rule is not difficult to find. It is a tautology that, on any given question, there is at least as much relevant information in n heads as there is in any one of them. On the other hand, it is equally a tautology that there is at least as much misinformation in n heads as there is in one. And it is certainly not a tautology that there exists a technique of extracting the information in n heads and putting it together to form a more reliable opinion. With a given procedure, it may be the misinformation that is being aggregated into a less reliable opinion. The n-heads rule, then, depends upon the procedures whereby the n heads are used.

Dalkey goes on to point out that in the case of numerical estimates,

> the probability that the median is at least as close to the true answer as any individual response is at least one half; for the mean, the error of the mean (measured by the distance to the true answer)

> is less than or equal to the average error of the individual answers. These two criteria are not equivalent, and for different decision situations one or the other could be more appropriate (Ref 19, p 16).

A set of experiments was conducted, at Rand, to examine the "dependence on group size of the mean accuracy of a group response" (Ref 19, p 17). Figure 3, from a Rand paper by Dalkey et al, presents the data obtained from these experiments. The data was developed from a large set of answers groups gave to factual questions where the answers were known to the experimenter but not the subjects. "The curve was derived by computing the average error of groups of various sizes where the individual answers were drawn from the experimental distribution.--The group error is the absolute value of the natural logarithm of the group median divided by the true answer." Dalkey comments that

> It is clear from the figure that with this population of answers, the gains in increasing group size are quite large. It is interesting that the curve appears to be decreasing in a definite fashion, even with groups as large as twenty-nine. This was the largest group size we used in our experiments (Ref 19, p 17).

In discussing the use of this data for determining what constitutes a substantial size group in regard to expected accuracy, Dalkey et al state that the appropriate size "is not sharply determined by the curve." They "selected 7 as the lower limit on the grounds that it was roughly in the middle of the 'knee' of the curve" (Ref 20, p 6).

Dalkey brings out another facet of the influence of group size when he discusses reliability.

> Another important consideration with respect to the n-heads rule has to do with reliability. The most uncomfortable aspect of opinion from the standpoint of the decision maker is that experts with apparently equivalent credentials (equal degrees of expertness) are likely to give quite different answers to the same question. One of the major advantages of using a group response is that this diversity is replaced by a single representative opinion. However, this feature is not particularly interesting if different groups of experts, each made up of equally competent members, come up with highly different answers to the same question.

Using the same data obtained in the experiments on accuracy as a function of group size, a curve was constructed by the Rand group which shows the relationship between reliability and group size. This curve is reproduced in Figure 4.

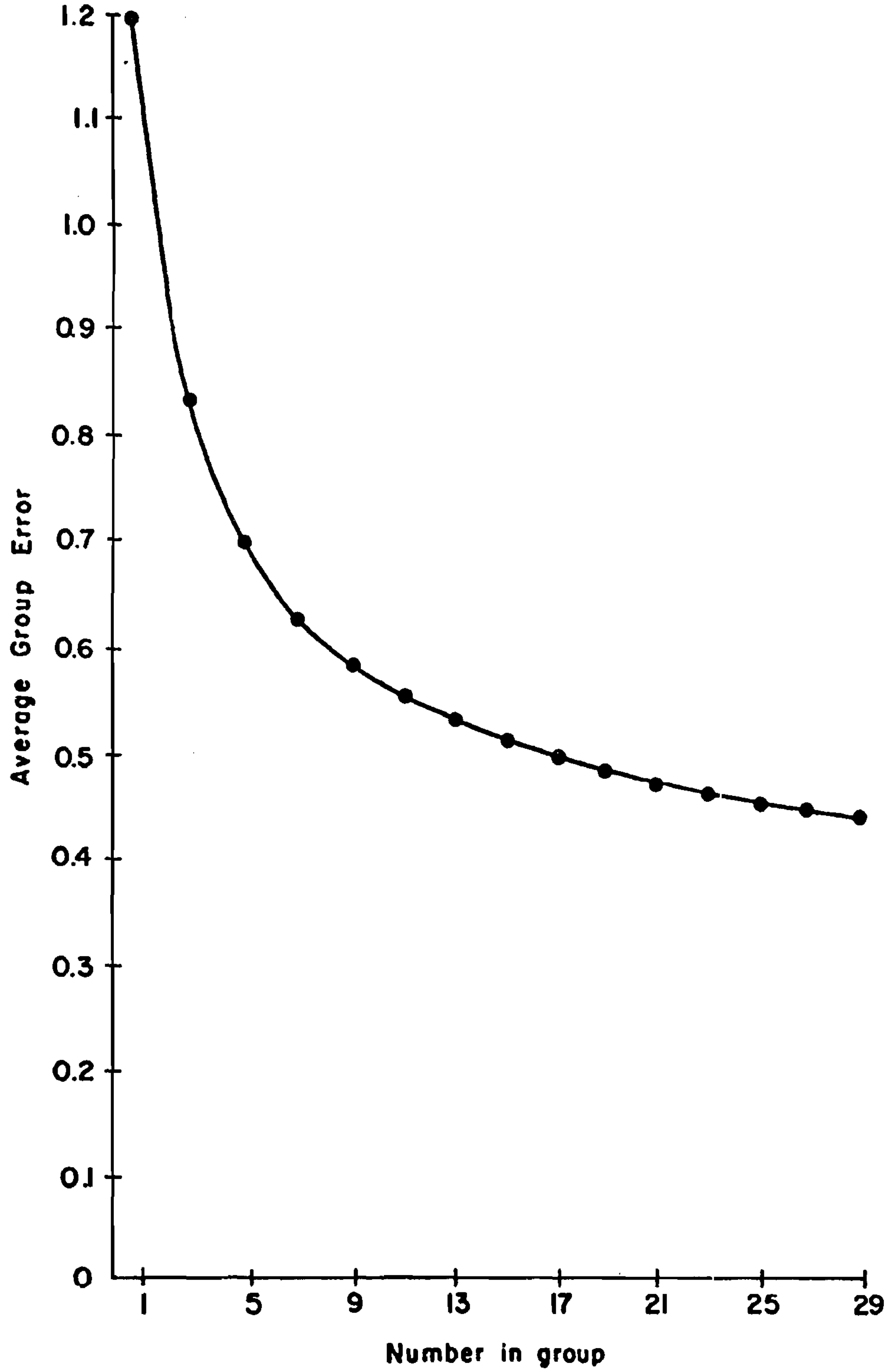

Fig 3. Effect of group size (after Dalkey et al, Ref 20).

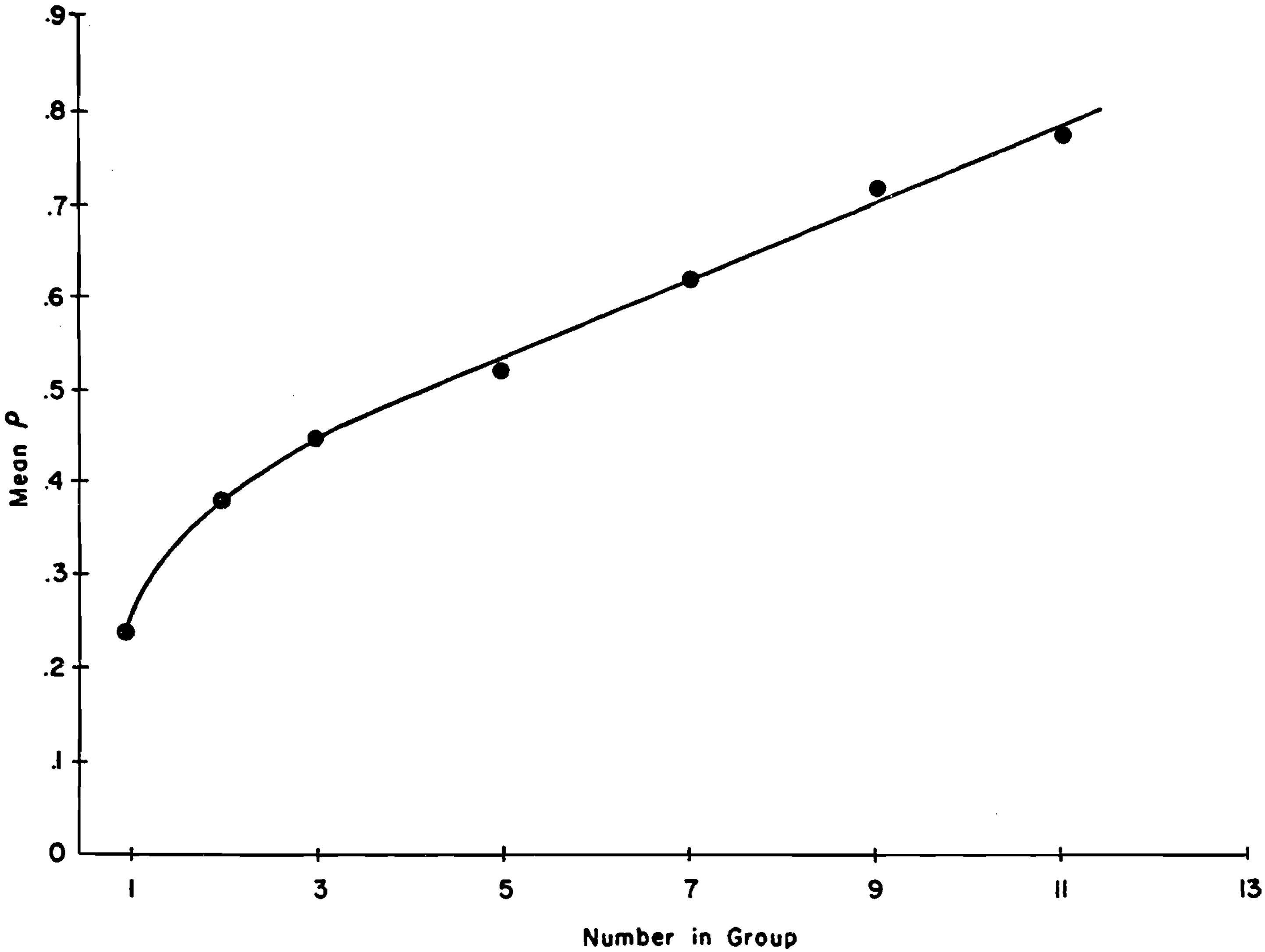

Fig 4. Reliability vs. group size (after Dalkey, Ref 17).

> It was constructed by selecting at random pairs of groups of respondents of various sizes and correlating the median responses of the pairs on twenty questions. The ordinate is the average of these correlations.
>
> It is clear that there is a definite and monotonic increase in the reliability of the group responses with increasing group size. It is not clear why the relationship is approximately linear between n=3 and n=11.

In commenting on the results of these experiments Dalkey concludes that "in the area of opinion, then, the n-heads rule appears to be justified by considerations of both improved accuracy, and reliability" (Ref 19, pp 18-19). This information on the effect of group size will be referred to in Chapter 4 which develops the experimental design for testing hypotheses regarding the influence of cognitive style in the data base design process.

The 1953 study, in which Dalkey and Helmer initially introduced the feature of iteration with controlled feedback, is interesting both from a historical perspective and also for the many facets of the technique that it presents. "The experiment was designed to apply expert opinion to the selection, from the viewpoint of a Soviet strategic planner, of an optimal U.S. industrial target system and to the estimation of the number of A-bombs required to reduce the munitions output by a prescribed amount" (Ref 22, 458).

> Seven experts participated, responding to five questionnaires submitted at approximately weekly intervals. The first questionnaire was followed by an interview in which each respondent was asked to reproduce the reasoning by which he arrived at an estimate of the number of bombs and to show the component breakdown by industries. The third also was followed by an interview for the clarification of ambiguities. The choices of target systems were quite distinct, the only common feature being the inclusion of the steel industry in each. The numerical quantity being estimated showed considerable convergence. The ratio between the largest and smallest response was about 100 to 1 on the initial round but had dropped to about 3 to 1 on the final round (Ref 6, p 9).

This example illustrates three of the basic features of Delphi: "(1) Anonymity. The opinions of the group are recorded separately--usually by questionnaire--and when communicated to other members of the group are not attributed to specific individuals. (2) Controlled feedback. An exercise is conducted in several rounds in which the opinions generated during one round are fed back to the group on the next round, usually in the form of statistical summaries. (3) Statistical group response. The 'group opinion' is expressed in terms of a statistical score--the median of final responses has proved to be most suitable for numerical estimates. There is no pressure to arrive at a 'consensus'" (Ref 18, p 4).

> Anonymity, effected by the use of questionnaires or other formal communication channels, such as on-line computer communication, is a way of reducing the effect of dominant individuals. Controlled feedback--conducting the exercise in a sequence of rounds between which a summary of the results of the previous round are communicated to the participants--is a device for reducing noise. Use of a statistical definition of the group response is a way of reducing group pressure for conformity; at the end of the exercise there may still be a significant spread in individual opinions. Probably more important, the statistical group response is a device to assure that the opinion of every member of the group is represented in the final response. Within these three basic features, it is, of course, possible to have many variations.
>
> There are several properties of a Delphi exercise that should be pointed out. The procedure is, above all, a rapid and relatively efficient way to "cream the tops of the heads" of a group of knowledgeable people. In general, it involves much less effort for a participant to respond to a well-designed questionnaire than, for example, to participate in a conference or to write a paper. A Delphi exercise, properly managed, can be a highly motivating environment for respondents. The feedback, if the group of experts involved is mutually self-respecting, can be novel and interesting to all. The use of systematic procedures lends an air of objectivity to the outcomes that may or may not be spurious, but which is at least reassuring. And finally, anonymity and group response allow a sharing of responsibility that is refreshing and that releases the respondents from social inhibitions (Ref 19, p 21).

Another aspect of Delphi that is demonstrated in the U.S. industrial target system example is the method's ability to come to grips with problems that involve uncertainty and value judgments. Dalkey states that "in those cases where a group of knowledgeable individuals reports a wide diversity of opinion, it would seem that in the majority of cases no one knows the answer. In fact, the diversity of opinion is a relatively good measure of the degree of lack of knowledge concerning the question."

> The first basic consideration in the Delphi approach, then, consists in recognition of the high degree of uncertainty that surrounds important questions--especially questions with value content--and relaxing the desire to find the so-called right answer. It then becomes meaningful to ask how the diversity of information that leads to disagreement within the group can be amalgamated to lead to the best available answer to the question. Actually, even this weaker

> aim is too strong at present. There are many features of the judgmental process which we understand too poorly to define *best*, much less specify practical rules for attaining it. At present we are limited to rules for finding *better* answers to uncertain questions (Ref 19, p 4).

Since a data base is customarily used at some future time, by some undetermined group of people, as an aid in making some as yet unspecified decision; uncertainty is inherent in any attempt to determine what the contents of the data base should be. As will become clearer when the cognitive style concept is reviewed in greater detail later in this chapter, there are also innate differences of opinion or different value judgments amongst different users as to what types of information may be important even if all of the above uncertainties were completely specified. If the Delphi approach is in fact capable of producing better answers than other known methods when dealing with problems involving uncertainty and value judgments, this is a significant recommendation for the consideration of the use of the technique as a method for data base design. Throughout the remainder of this section, which reviews the literature on Delphi, evidence will be presented that will undoubtedly lead the reader to conclude that such a recommendation is indeed warranted.

In order to investigate the question of whether "the use of iteration and controlled feedback have anything to offer over the 'mere' statistical aggregation of opinions," an extensive series of experiments has been conducted at Rand. A secondary objective of these experiments was "to get some measure of the value of the procedures, and also to obtain, as a basis for improving the procedures, some insight into the information processes that occur in a Delphi exercise." In discussing one set of these experiments Dalkey has stated that

> We used upper-class and graduate students, primarily from UCLA, as subjects. They were paid for their participation. For subject matter we chose questions of general information, of the sort contained in an almanac or statistical abstract. Typical questions were: "How many telephones were in use in Africa in 1965?" "How many suicides were reported in the U.S. in 1967?" "How many women marines were there at the end of World War II?" This type of material was selected for a variety of reasons: (1) we wanted questions where the subjects did not know the answer but had sufficient background information so they could make an informed estimate; (2) we wanted questions where there was a verifiable answer to check the performance of

individuals and groups; and (3) we wanted questions with numerical answers so a reasonably wide range of performance could be scaled. As far as we can tell, the almanac type of question fits these criteria quite well. There is the question whether results obtained with this very restricted type of subject matter apply to other kinds of material. We can say that the general-information type of question used had many of the features ascribable to opinion: namely, the subjects did not know the answer, they did have other relevant information that enabled them to make estimates, and the route from other relevant information to an estimate was neither immediate nor direct.

The general outcome of the experiments can be summarized roughly as follows: (1) on the initial round, a wide spread of individual answers typically ensured; (2) with iteration and feedback, the distribution of individual responses progressively narrowed (convergence); and (3) more often than not, the group response (defined as the median of the final individual responses) became more accurate. This last result, of course, is the most significant. Convergence would be less than desirable if it involved movement away from the correct answer (Ref 19, pp 21-22).

In discussing this same set of experiments, in a different reference, Dalkey has made the additional comment that the principle decrease in the spread of opinions occurs between the first and second rounds, and he states

> We have concentrated on the closed information case; i.e., during the exercise, no new information concerning the subject matter is introduced into the group. Even in this case, the accuracy of the group response increases with iteration--rather like lifting itself by its logical bootstraps on the part of the group (Ref 18, p 5).

In order to extrapolate the findings of the above described set of experiments that dealt with factual data, i.e. almanac type questions, to the area of opinion and value judgments; the Rand group established three conditions "as a partial definition of the term group judgment for value questions."

(1) *Reasonable distributions.* If the distribution of group responses on a given numerical value judgment is flat, indicating group indifference, or if it is U-shaped, indicating either that the question is being interpreted differently by two subgroups, or there is an actual difference of assessment by two subgroups, then it seems inappropriate to assert that the group considered as a unit has a judgment on that question.

(2) *Group reliability.* Given two similar groups (e.g., two groups selected out of a larger group at random) the group judgments on a given value question should be similar. Over a set of such value judgments, the correlation for the two subgroups should be high.

(3) *Change, and convergence on iteration with feedback.* This condition is proposed in part by analogy with results from experiments with factual material, that is, shifts of individual responses toward the group response and reduction in group variability. More generally, if members of the group do not utilize the information in reports of the group response on earlier rounds when generating responses on later rounds, it seems inappropriate to consider these responses as judgments.

The Rand group then, in another set of experiments, applied the three criteria "to value judgments by university students concerning the objectives of a higher education and the objectives of everyday (individual) life."

> The students generated a list of objectives for these two areas, and rated them on a scale of relative importance. Three different rating methods were employed in order to test both group reliability and stability over scaling technique. Ratings were obtained on each of two rounds, where the results of the first round (the median and upper and lower quartiles of the responses) were fed back between rounds. The data generated by the value judgments satisfied the three criteria to about the same degree as corresponding data from similar groups making factual estimations. In short, the outcome of these experiments appears to be that the Delphi procedures--as far as we can evaluate them at present--are appropriate for generating and assessing value material (Ref 19, p 57).

In a series of experiments conducted by Robert M. Campbell (Ref 10) the Delphi Technique was compared to traditional methods of integrating group opinion. Campbell used students from two graduate seminars in business forecasting at UCLA. The two sections were each randomly divided into two groups. One group of students from each of the two sections were asked to predict sixteen economic indicators a quarter in advance. The two groups were allowed to interact freely amongst themselves and use any methods they felt appropriate in arriving at a group estimate. These two groups were designated as the traditional groups. The remaining two groups were also asked to predict the same indicators, but were required to use the Delphi process in making their predictions. Four rounds of the Delphi process were conducted over a six week period, and in thirteen cases the Delphi process proved to be more accurate. The normal forecasting techniques, carried out in the context of face-to-face interaction, were more accurate in only two cases. Similar studies at Rand have confirmed this highly favorable result (Ref 19, p 24).

In the case of data base design we are not only concerned with perfecting a method that will tap the expertise of the most knowledgeable people, i.e., the potential users, but we are also concerned with the possible effect that such participation may have on the attitude of the users toward the system. In this vein, Dalkey comments that he believes the features of a Delphi exercise are desirable especially "where group acceptance is an important consideration" (Ref 19, p 21). In another instance he says

> I can state from my own experience, and also from the experience of many other practitioners, that the results of a Delphi exercise are subject to greater acceptance on the part of the group than are the consensuses arrived at by more direct forms of interaction (Ref 17, p 17).

The self rating aspect of the Delphi method is also worthy of brief mention because it is used in the Delphi type methodology for data base design that is proposed in the next chapter. Olaf Helmer discusses the self-rating concept.

> A refinement which has already been successfully tested is that of attributing differential weights to the opinions of different experts. Clearly, if it were easy to measure the relative trustworthiness of different experts, we would give greatest weight to the opinions of those who are most trustworthy. In the absence of objective measurements to this effect, we have examined the possibility of relying instead on the experts' subjective self-appraisal of their own competence, and found this quite promising (Ref 43, p 7).

In addition to providing the ordinary information required by the Delphi process, the participants are also asked to rank the items under consideration with respect to the competence that they have in making their judgment. This ranking is best thought of as an index of self-confidence or self-rated competence in regard to each particular item. The Rand experiments alluded to by Helmer required each participant to provide a self-rating, "based on a scale of 1, 2, 3, or 4," which indicated "an evaluation of his own degree of expertise on each question" (Ref 7, p 4). Then, instead of using the median as the group consensus, as is common at Rand, "only the responses of those individuals were taken who had ranked their competence regarding that index relatively most highly; and the median of just these forecasts was then used as the group consensus. It subsequently turned out that this select median, compared to the median of all responses, was closer to the true value in two thirds of the cases" (Ref 43, p 8).

Examination of the various aspects of the Delphi process, that are reviewed above, led this writer to conclude that a Delphi type methodology is, in theory, highly suited to the problem of data base design. The remaining chapters in this report discuss an experiment, to test this theory, that was conducted within the context of applying Delphi to the design of a highly complex, real life data base. The cognitive style of the participants in a data base design process was viewed as being a possible factor that might influence the manner in which Delphi groups should be structured; therefore, the next section of this review examines the cognitive style concept.

Cognitive Style

Michael Wallach comments that "the word style has entered psychology's technical vocabulary to signify certain kinds of generality--that someone who reacts in one manner in one situation will react in a particular characteristic way in another" (Ref 67, p 199). Thus, the designation *cognitive style* refers to the application of the style concept to individual consistencies in certain cognitive areas, such as perception and intellectual functioning. By concentrating on the perceptual organization and adaptation aspects of cognitive functioning, it is possible to generate a definition of cognitive style germane to the central focus of this study, i.e. the design of data bases for information systems. *Cognitive style* can be defined, for our purposes, as the self consistent manner in which an individual extracts information from his environment and uses this information in his problem solving and decision making activities.

Some of the possible implications that cognitive style holds for the design of information systems can be found in the work of Huysmans and also in the work of Doktor and Hamilton that were referred to briefly in Chapter 1. Huysmans conducted a laboratory experiment in which he investigated the factors that influence managerial implementation behavior in regard to operations research recommendations. In particular he was concerned with "the difference in cognitive styles between manager and operations researcher" (Ref 46, p 92). Huysmans' experiment was conducted in "the format of a business game in which one 'president' and four 'managers' made financial, pricing, production, and purchasing decisions for a hypothetical firm during several 'decision periods'" (Ref 46, p 94). The four managers, whose roles were simulated, presented advice to the president who was solely responsible for making the decisions for the firm. The president's role was the only role filled by an experimental subject. These subjects were selected from MBA students at the University of California at Berkeley.

The experimental subjects were classified into the two categories of analytic or heuristic according to their predominant ways of reasoning. The analytic type "reduces problem situations to a core set of underlying causal relationships. All effort is directed towards detecting these relationships and manipulating the decision variables (behavior) in such a manner that some 'optimal' equilibrium is reached with respect to the objectives. A more or less explicit model, often stated in quantitative terms, forms the basis for each decision." The heuristic type "emphasizes workable solutions to total problem situations. The search is for analogies with familiar solved problems rather than for a system of underlying causal relationships, which is often thought illusory. Common sense, intuition, and unqualified 'feelings' about future developments play an important role to the extent they are applied to the totality of the situation as an organic whole, rather than as built up from clearly identifiable separate parts. It is extremely difficult, if not impossible, to uncover the mechanisms that lead to a decision under hueristic reasoning. The resulting decision, however, can be characterized by its emphasis on consistency with its internal and external environment in contrast with the decision of an analytic reasoner which emphasizes optimality" (Ref 46, pp 94-95).

The experimental subject, who was unaware of the true nature of the research effort, was presented with an operations research recommendation based on "an extended version of the 'newsboy' problem" which was applicable to the decisions the hypothetical president was being asked to make. The recommendation was not identified as an operations research proposal.

> Two different implementation strategies--one aimed at gaining the subject's "explicit," the other at gaining his "integral," understanding of the operations research proposal--were expressed through two versions of the simulation rules that governed the accounting manager's communications. Both versions contained sufficient and similarly

> presented arguments to enable the "president" to gain a general appreciation for, and an integral understanding of, the research done. The only essential difference between the versions consisted of the inclusion of formulas to support the research findings when the "explicit-understanding" approach was used (Ref 46, p 96).

"A subject's adoption/rejection behavior with respect to the OR recommendations was measured largely on the basis of his marketing and production decisions" (Ref 46, p 96).

It was found that analytic subjects reached a higher degree of implementation than heuristic subjects when the accounting manager used the "explicit-understanding" approach in presenting the operations research proposal. It was also found that the heuristic and analytic subjects who received the "integral-understanding" approach reached a higher degree of implementation than the heuristic subjects who received the "explicit-understanding" approach. From the results of this research, Huysmans concluded that

> (a) Cognitive style may operate as an effective constraint on the implementation of operations research recommendations
>
> (b) The operations researcher may achieve implementation by taking this implementation constraint into account in his research strategy
>
> (c) When the cognitive-style propensities of operations researcher and manager do not agree, the manager may discard the operations researcher completely as a source of information: A research recommendation will not be implemented no matter how persuasive and intuitively appealing the operations researcher's arguments may be, simply because the manager has no serious intention of considering it in the first place (Ref 46, p 101).

Following the lead of Huysmans, Doktor and Hamilton conducted an experiment "to examine the effects of cognitive style on the managerial acceptance of management science recommendations presented in written form." The subjects in the experiment were classified along the field independence/dependence dimension of cognitive style through the administration of a paper and pencil test that was modified from Witkin's original Embedded Figures Test.[1] The subject (*S*) "was then asked to read a simple business case which was adapted from one used by Huysmans."

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[1]The work of Witkin and his associates, in identifying and developing the field independence/dependence concept, will be discussed in a subsequent part of this section.

S was asked to assume the role of top management in the case situation. Next, S was presented with one of two versions (R_1 or R_2) of a "consultant's report". R_1 and R_2 were distributed alternately among S according to rank on the Witkin test. After considering the report, S was asked to record on a simple questionnaire whether or not he would accept the consultant's recommendations.

The consultant's reports contained identical analyses of the case problem and the same recommended solution, but differed in organization and presentation style. The major differences in the formats of the two reports can be summarized as follows:

Report 1 (analytic)	*Report 2 (general)*
(1) Problem Review	(1) Recommendation
(2) Alternatives	(2) Benefits
(3) Choice Criterion	(3) Alternatives
(4) Evaluation	(4) Evaluation
(5) Recommendation	(5) Problem Review
(6) Benefits	(6) Choice Criterion
(7) Appendix	(7) Appendix

The appendix of R_1 contained only data tables, while the appendix of R_2 also included all mathematical details (e.g., the regression model) involved in the analysis. In addition, R_2 was organized with numerous subheadings. The style of organization of R_1 was classified as analytic and, like Huysmans' explicit treatment condition, R_1 contained formulas in the main body of the report. The style of R_2 was classified as general. It is the style often suggested by management consultants in order to achieve "more effective implementation" (for example, see Neuschel [13]). Like Huysmans' implicit treatment condition, R_2 contained no formulae or other technical material in its main body, leaving such "mathematical details" to the appendix (Ref 27, pp 888-889).

Doktor and Hamilton's experimental subjects were drawn from two separate populations: (1) graduate business students from an introductory MBA course at the Wharton School, and (2) practicing managers attending a "voluntary, one-day seminar on implementation problems in the management sciences." The availability of both graduate business students and practicing managers for inclusion in the same experiment was a fortuitous occurrence in regard to the results that were obtained.

Although limited sample sizes did not allow detailed evaluation of the results, it was demonstrated that managerial acceptance behavior is influenced by the style of presentation of management science recommendations. Different reporting styles were observed to have different acceptance rates. Further, when sample sizes were expanded through use of student subjects it became apparent that different cognitive styles yielded different acceptance rates for the two presentation styles under study.

The results also indicate that the use of student surrogates--even graduate business student surrogates--in experiments involving

> managerial decision-making behavior can be misleading. When a subsample of the student group was matched to the Witkin scores of the manager group, the students showed a significantly greater propensity to accept a report independent of its style. This challenges the validity of generalizations from the behavior of MBA student subjects to the behavior of managers a not uncommon practice in management research. . . . This clearly suggests a need to replicate previous experiments which have investigated managerial behavior using student subjects. Such replications should, of course, employ practicing managers as subjects. Furthermore, caution should be exercised in applying principles derived from the generalizations of these earlier experiments until the results of the replications have been reported and analysed (Ref 27, pp 891-892).

The results of these two studies tend to indicate that cognitive style could act as a possible influence in the design of data bases for information systems. For example, the successful implementation of data base systems might be retarded by a failure to include certain categories of data that those individuals with particular cognitive styles might prefer. The experimental effort described in this report examines this type of possibility in the design of a data base for an actual organization. Managers from all levels within the Texas Highway Department participated in a Delphi process to design the Pavement Feedback Data System (PFDS) data base, and the Delphi groups in which these individuals participated were structured relative to a dimension of cognitive style. Therefore, in this section a review of the cognitive style literature will be undertaken with the objective of presenting, in a highly summarized form some of the many diverse dimensions that have characterized the development of the concept. The cognitive style dimension that was selected for use in the PFDS data base design project will be discussed in more detail in Chapter 5, Measurement Instruments.

Heinz Werner, in his foreword to Witkin et al (Ref 91), attempts to offer a historical perspective on the development of the cognitive style concept. He states that

> The beginnings of these investigations can be traced back to the work of Gestalt psychologists who were in constant search for perceptual situations that would demonstrate the dependency of perceptual properties of parts of the field on the (visual) field structure as a whole. In exploring such situations involving the perceptual property of the "upright" and using (in collaboration with Dr. Asch) the famous mirror set-up of Wertheimer, Witkin soon discovered that neither the interpretation in terms of universal visual Gestalt principles, such

> as that of part-whole relation, nor the interpretation in terms of postural factors (Gibson) suffices to account fully for the behavioral effects in the subjects. Moving away from an orthodox Gestalt-view as one "encapsulated within the organism" (Brunswik), Witkin showed that a rather satisfactory explanation could only be attained through an analysis in terms of individual differences (Ref 91, p vii).

The individual differences observed were "that people differ in the way they orient themselves in space." In addition it was found "that the way in which each person orients himself in space is an expression of a more general preferred mode of perceiving which, in turn, is linked to a broad and varied array of personal characteristics involving a great many areas of psychological functioning" (Ref 91, p 1). Thus, Witkin and his coworkers, with their identification of the two individual modes of perception they labeled field-dependent and field-independent (Ref 90), established the first cognitive style dimension.

Witkin and his coworkers, in discussing the concept of a general preferred mode of perceiving, state that

> The scope of individual consistency in this respect is suggested by a brief consideration of some of the attributes of people who show, in their orientation, what we call a "field-dependent" way of perceiving. This kind of orientation, observable in any of a series of tests devised for our early studies, may be illustrated by performance in the rod-and-frame test. The subject in this test sits in complete darkness, facing a luminous rod surrounded by a luminous frame. Rod and frame can be independently tilted, to one side or the other; the subject sees them first in tilted positions. Then, while the frame remains tilted, he moves the rod (through his directions to the experimenter) until it appears to him that it is vertical. Some subjects tip the rod far towards the angle of tilt of the frame in order to perceive it as upright, thus determining its position mainly in relation to the visual field that immediately surrounds it. Here and in other perceptual situations these subjects find it difficult to overcome the influence of the surrounding field or to separate an item from its context. It is because of this characteristic that their perception has been designated field dependent. Other subjects, in contrast, are able to bring the rod close to the true upright, perceiving it independently of the surrounding field and determining its location with reference to body position. In perceptual situations generally, such people are able to distinguish an item from its context. Their perception is field independent. In the general population performances reflecting the extent of people's field dependence or independence are ranged in a continuum rather than falling into two distinct categories. . . .
>
> Field-dependent people take a rather long time to locate a familiar figure hidden in a complex design. Because they are less likely to

> attempt to structure ambiguous stimuli, as Rorschach inkblots, they usually experience such stimuli as vague and indefinite. They often find difficulty with the block-design, picture-completion, and object-assembly parts of standard intelligence tests. Yet, they are no different from more field-independent people on other portions of intelligence tests which require concentrated attention; and they may even do better on portions concerned with vocabulary, information, and comprehension. They are also not different from field-independent people in the ability to learn new material. In Duncker's well-known insight problems they may not readily see alternative uses for items serving a familiar function (Ref 91, pp 1-2).

They also point out that people who demonstrate "a predominantly field-independent way of perceiving present a direct contrast in many of these attributes" (Ref 91, p 3).

In order to overcome the difficulty involved in administering the rod-and-frame test to large numbers of subjects, Witkin and his associates developed a paper and pencil test to measure the field/dependence-independence concept. "The subject's task is to find a particular simple figure within a larger complex figure. The figures which make up the test were selected from those developed by Gottschaldt (1926) for his study of the role of past experience in perception" (Ref 91, p 39). This test is called the Embedded Figures Test, and a modified version of the original test was used by Doktor and Hamilton in their study.

Both the rod-and-frame test and the embedded figures test have the common property that they require the subject to "keep an item separate from a field or embedding context. The item might be . . . a stick in the rod-and-frame test, or a geometrical figure in the embedded figures test."

> In these situations, for the relatively field-dependent subjects, object and field tend to "fuse," so that the separation called for by the task cannot easily be made. In this sense, the more field-dependent subjects' experience can be characterized as global. In contrast, the performance of a relatively field-independent person, who is able to keep object and field separate, can be termed analytical. It should of course be noted again that the terms "global" and "analytical" refer to extremes of a dimension represented by a continuous distribution of scores on perceptual tests (Ref 67, p 172).

"The global vs. analytical style of experiencing . . . extends to a wide variety of intellectual tasks," and "thus becomes a designation for a cognitive style which expresses itself in both perceptual and intellectual functioning" (Ref 67, pp 173-174).

Other investigators, subsequent to Witkin, have identified additional "cognitive controls," and the global vs. analytical mode of cognitive style can be viewed as one of several dimensions of the cognitive style concept. A couple of these other dimensions will be briefly reviewed in order to present the reader with an opportunity to gain some insight into the complexity and lack of a unifying theory that characterizes the present rudimentary state of the cognitive style concept.

"The Leveling-Sharpening principle is currently defined in terms of individual consistencies in the degree to which new experiences interact or 'assimilate.' Subjects at the sharpening end of the continuum are those who show a minimum of such mutual assimilation, subjects at the leveling end show relatively great assimilation" (Ref 67, p 195).

"The Scanning principle was originally inferred primarily from individual consistencies in response to size-estimation tests. The individual consistencies observed in simple size judgments also seemed apparent, however, in other situations tapping the extensiveness with which persons sample both external stimuli and internal memory schemata under relatively 'free' conditions. Some persons seem to sample extensively, whether or not this degree of sampling is necessary for effective performance in the task at hand. Such sampling may even be a handicap under certain circumstances in that it increases decision time. Others seem to attend primarily to 'dominant' objects in the field and in other ways to scan in a relatively restricted manner" (Ref 67, p 191).

A recent research effort has been made by a research group working under Professor James McKenney at the Harvard Business School to develop a unified model of cognitive style. Peter Keen, one of McKenney's associates in the project has commented that

> theories of cognitive style all have the distinctive weakness of locality; in some cases all they really show is that subjects do well or badly on the tests used to identify the specific styles. Equally important is the general tendency for models of style to postulate a single dimension with positive-negative poles. . . . The weakness of any uni-dimensional model of human thought processes is simply that it seems unlikely that it can do justice to the complexity of human thinking. To fit the immense range of capacity and responses that any capable adult demonstrates over a variety of settings into a single polarized dimension is inevitably to limit the applicability of the model in question (Ref 54, Chap 1, p 12).

The Harvard group postulates a model of cognitive style composed of two "relatively separable factors, information-gathering and information-evaluation." The model "defines the information-gathering dimension in terms of two extremes of behavior, Receptive and Preceptive."

> 'Preceptive' individuals tend to bring to bear concepts that they use to filter data; they focus on patterns of information, look for deviations from or conformities with their expectations. Their precepts act both as cues for information-gathering and as heuristics for cataloguing what they find. By contrast, the 'Receptive' thinker is much more sensitive to the stimulus itself. He will focus on detail rather than on pattern and tries to derive the implications of the data from direct examination instead of from its fitting his precepts. Each mode has advantages in specific situations; equally, each includes risks of overlooking the potential meaning of data. The Preceptor too easily ignores relevant detail while the Receptor may fail to shape detail into a coherent whole. In management positions the Receptor may be most successful in tasks such as auditing and the Preceptor in many marketing and planning roles.
>
> The second dimension of style, information-evaluation, refers to processes commonly subsumed under the term 'problem-solving'. Individuals differ both in how they use data in reaching a decision and in the sequence of their analysis. These differences are most pronounced in relation to planning. The model argues that 'Systematic' thinkers tend to approach a problem by structuring it in terms of some method which if followed through leads to a likely solution, while 'Intuitive' individuals usually avoid committing themselves in this way; their approach is much more one of hypothesis-testing and trial-and-error. They are much more willing to jump from one method to another, to discard information and to be sensitive to cues that they may not be able to identify verbally. Here again, each mode of evaluation has risks and advantages. In tasks such as production management a Systematic individual can develop a method of procedure - a program - that utilizes all his experience. By contrast the Intuitive is often better able than the Systematic to approach ill-defined problems where the volume of data, the criteria for action or the nature of the problem itself do not allow the use of any predetermined plan (Ref 54, Chap 2, pp 1-2).

Figure 5 presents a paradigm of the cognitive style model developed by the Harvard group. The vertical axis reflects the information gathering dimension of the model, while the horizontal axis presents the information evaluation dimension. A particular cognitive style is defined by the quadrant in which the individual's style falls, e.g. Systematic-Receptive or Intuitive-Preceptive.

Keen discusses the impact that cognitive style research is likely to have on the area of information systems design. He states that "one long-term

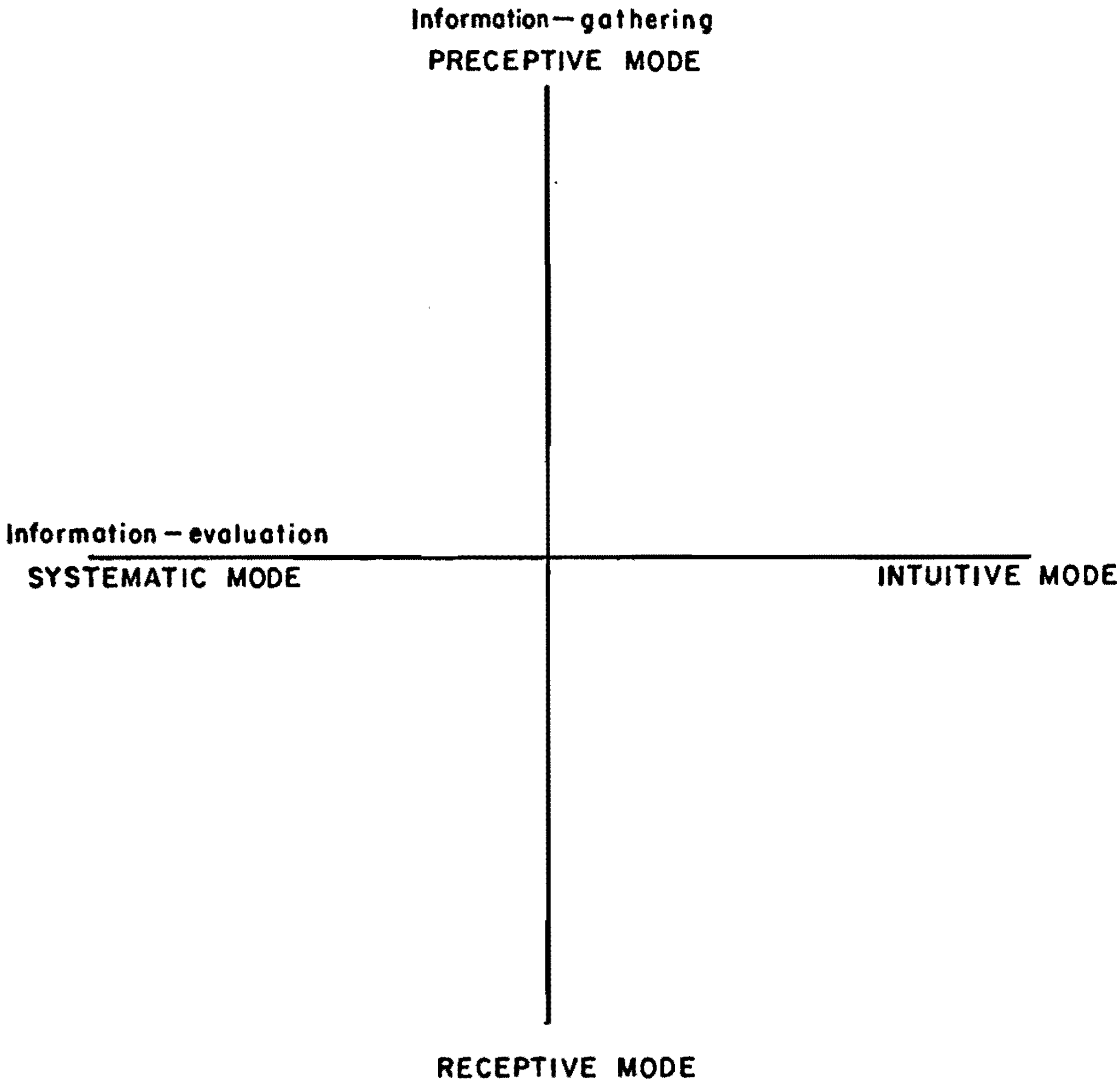

Fig 5. A model of cognitive style (after Keen, Ref 54).

output of the cognitive style research may well be a taxonomy of information." He feels that the organization's "MIS acts as a cognitive filter, selecting and organizing data from the environment. The computer system which generates the information explicitly uses concepts of what data is relevant, how it should be formatted, etc." If the fit between the user's cognitive style and the information contained in and output from an MIS is not taken into consideration, unintended changes may take place in the user's problem solving behavior; "the consequences thereof may be unanticipated." Keen demonstrates this by pointing out, in terms of the Harvard cognitive style model, how individuals with Systematic and Intuitive styles approach and justify their solutions to problems.

> The two modes of style result in very different ways of justifying solutions. The Systematic individual can validate his decision process by recapturing his sequence of problem-solving. He can in fact lay out the program he followed. He explicitly defined the problem, chose a strategy and progressed methodically, analysing and evaluating alternatives in relation to that strategy. The Intuitive, by contrast, cannot show his sequence of thought. He can often only backward induct, pointing first to his solution and then showing how it is consistent with the features of the problem. In some cases he may not explicitly comprehend but only sense that some data or assessment has a particular relevance. In the last resort, the Intuitive thinker can only justify the solution to a complex elusive problem by saying 'trust me; my instinct tells me it's right'. Successful Intuitives do build up a track record that gains them such trust. Unfortunately they also may tend to justify a solution, particularly to a Systematic superior, through a pseudorationalization. It is in such situations that Intuitives get a reputation for careless thinking, since their explanation does not in fact match their problem-solving process; they are not facile in systematic evaluation and the superior can quickly pick holes in the reasoning or point to jumps in the argument that may be valid but are not validated. The question of how one can or should validate a solution is very complex indeed. The issue to be raised here is that the different modes of style pose distinct problems of communication; once again, it must be stressed that neither style is better than the other. The Systematic manager is not justified in dismissing the Intuitive as scatter-brained because he cannot rationalize his decision. On the other hand, the Intuitive cannot take for granted his 'obvious' solution ought to be obvious to others (Ref 54, Chap 3, pp 54-58).

<u>Summary</u>

Several experiments on the Delphi Technique, which were conducted by the Rand Corporation who are the originators of the method, were reviewed.

These experiments provide evidence that a large number of people are more accurate and reliable than a few in making judgments as to both factual and opinion type of material. The experiments also show that the introduction of iteration and controlled feedback serves to increase the accuracy of a group response, and that a consensus reached through a Delphi process is, in most cases, more accurate than that obtained through face-to-face interaction. Opinions as to the efficacy of the Delphi process in promoting group acceptance were reported, and various aspects of the Delphi Technique were examined. It was concluded that, at least in theory, a Delphi type methodology is highly suited to the problem of data base design.

A brief review of the cognitive style literature was conducted, and two experiments indicating that cognitive style is likely to be a factor in the development of information systems were examined. The seminal work of Witkin and his associates in the identification and development of the field/dependent-independent dimension of cognitive style was investigated, and two other cognitive controls were defined. The efforts of a group, at the Harvard Business School, to develop a unified theory of cognitive style were discussed; and their cognitive style model was presented. Peter Keen's comments regarding the implications of this model for the area of information system design were reported.

The next chapter will utilize the information that was covered on the Delphi process in the development of a Delphi type methodology for data base design. Chapter 4 will then use information from both the Delphi and cognitive style reviews to establish an experimental design for investigating the possible influence of cognitive style in data base design procedures. Finally, Chapter 5 will again refer to this review when the selection of an appropriate cognitive style dimension and its associated measurement instrument is being discussed.

CHAPTER 3. A DELPHI METHODOLOGY FOR DATA BASE DESIGN

This chapter describes various modifications to the Delphi Technique that have been found to enhance the technique's suitability as a methodology for data base design. The types of information that can and probably should be obtained from the potential users of a data base information system through the use of the methodology are discussed; and a type of technical information, pertinent to data base design, that was identified as more difficult to obtain from the potential users of PFDS is examined. Methods of conducting a Delphi process for data base design are presented, and a generalized computer program for processing the Delphi information flows associated with a data base design effort is described. A description of the actual application of the methodology to the determination of what the contents of the Pavement Feedback Data System (PFDS) data base should be is provided throughout the chapter as an example to clarify the theoretical concepts that are involved.

Types of Information

The central theme underlying the proposed methodology is that there are certain types of information concerning what the contents of a data base should be that can be best provided by the most knowledgeable people in the area, i.e. the potential users of the system. This is particularly true in the case of integrated systems with common data bases. It is unreasonable to expect a systems analyst to possess expertise in the systems area and at the same time be knowledgeable enough in all other areas to be able to adequately prescribe for the users of the system their information needs. Even if it were possible to locate such a versatile individual or obtain this information through interviews with the potential users, difficulty would still be encountered in defining a set of data items that were congruent with the purposes of the organization for which the system was to be designed. No one individual can be expected to accurately make such an assessment since an organization is by definition a collection of individuals working together. The potential users of the system acting as a group should, therefore, theoretically be the best source of this information. For example, in the case of PFDS there are experts that deal mainly with rigid pavements, i.e. concrete, and other experts that deal mainly with flexible pavements, i.e. asphalt. At the same time other experts in functional areas such as maintenance are required to work with both pavement types. The objective is to identify a parsimonious set of data items that concurrently satisfies all of the users' information needs and which is also conducive to the accomplishment of the organization's purpose.

Jerome Kanter postulates the existence of a phenomenon he calls the "geometric organizational syndrome" in his discussion of the problems inherent in achieving the "cooperation needed to arrive at the pertinent data elements" in a data base. He concurs that "joint decisions are needed to reach compromises related to the" data base content. However, he sees this as being a formidable task, since the number of communication pathways between an expanding number of people increases in approximately a geometric manner. He states that the "'geometric organizational syndrome' is probably even more accentuated by the psychological and political blocks that individuals bring with them to the situation. . . . The solution to these problems normally means discussions, meetings, and eventual compromise if the implementation time frame is to be met" (Ref 51, p 63).

A method, for overcoming the "geometrical organizational syndrome" in a manner that allows the potential users to identify the minimum set of data items necessary to satisfy the requirements of each user and the organization's purpose, is critically needed. The use of a Delphi methodology appears to be one large step toward the accomplishment of this objective. The question is what types of data base design information are the potential users capable of supplying.

In this section the focus will be on describing a set of information items that can be supplied and evaluated by the potential users through the use of the proposed Delphi methodology. Although these items to date have only been obtained in one actual application, i.e. PFDS, they are still felt to be generalizable to a large number of varied data base design situations. However, since the Delphi procedures can be easily modified to accommodate different or additional items, the primary purpose of this section is to demonstrate a functional class of data base design information items that can be obtained from the potential users through the use of the methodology. For example, if further research indicates that potential users who are experienced in data base systems are capable of supplying technical information such as a key/non-key designation or hierarchical ordering of the data elements, then these information items can be easily added to the Delphi procedures. In the PFDS experiment it was discovered that the participants, who were all inexperienced with data bases, had difficulty in supplying technical types of information. Therefore, only non-technical information items are used in the following description which is intended to demonstrate the potential of the Delphi method.

The primary item of information, that the potential users are capable of supplying, is a description of the elementary data items that should be included in the data base. The potential users thus need to provide descriptors or names for those data items they feel are important enough to warrant inclusion in the data base. These descriptors must necessarily be specified in enough detail to allow the administrator and all other participants in the process to unambiguously identify the data item being proposed.

In addition, the descriptor may also contain important information regarding the frequency with which the data item should be collected together with any dimensional information that might help to define the data item. The frequency portion of the descriptor can be broken down into both time and space components. For example, if a participant is desirous of describing a data item for the measurement of deflection along a segment of highway, he might provide the descriptor - ANNUAL DEFLECTION EACH .5 MILE. Annual describes the participant's feelings regarding the temporal frequency with which the data item should be collected, while the phrase, each .5 mile, reflects his opinions regarding the desirable spatial frequency for collection. Dimensional information, such as lbs/in^2, sq yds, etc, can also be supplied if it is necessary to resolve possible ambiguity. However, it should be pointed out that overspecification in the descriptors leads to the rapid proliferation of similar data items that the group must consider. Hence a dilution of effort on more important considerations takes place. In the application of the method, it appears advisable that the participants be apprised of this trade-off so they can limit the descriptors to significant phrases.

In the PFDS data base design effort, the information regarding the frequency of collection was considered to be quite important; and the participants were encouraged to take this into consideration in their formulation and evaluation of data item descriptors. However, engineering practice in the design and construction of highways was considered to be standardized to the point where any effort spent in supplying dimensional information would be unnecessary. Therefore, the participants were specifically requested not to include dimensional type of information in their data item descriptors.

On the first round of the Delphi process the participants are encouraged to submit descriptors for all data items they feel might be needed in the data base. The words, might be needed, are used because during the initial submission phase the emphasis is on developing all possible data items. In this regard, the participants should be specifically instructed to supply descriptors for all data items they think should be brought to the attention of the Delphi group. Even though a participant may personally feel that a particular data item is relatively unimportant it is still advantageous to have the group confirm or disconfirm this opinion. It should also be noted that the initial submission phase is completely uninhibited since the participants work individually during this stage of the process; therefore, it is quite likely that multiple descriptors with different wording, will be received which describe essentially the same data item. Techniques for handling this redundancy will be described in the next section of this chapter.

Then, in order to provide a means for group evaluation as to the merit of the data items that have been submitted, the participants are instructed to rate the items they submit in regard to importance. This importance rating reflects the participant's subjective opinion of how important he perceives the data item to be. During the successive iterations of the Delphi process, these importance ratings are repeatedly fed back to the participants who not only review the ratings on their own descriptors but also review the ratings on the descriptors supplied by other members of the group. Thus, the importance ratings are refined during each round of the process. Upon the convergence of the process, the importance rating reflects the group's collective judgment as to the relative importance of the various data items that were submitted.

Since the basic theme in applying a Delphi methodology to the design of a data base is the involvement of a representative spectrum of the potential users, a method for incorporating the necessarily wide range of expertise brought to each data item is required. This can be accomplished through a self-appraisal technique where each participant is asked to rate his expertise on each data item. This expertise rating reflects the participant's subjective judgment as to the degree of expertise he brings to a particular data item, or in other words the confidence he has in his assignment of the importance rating to a data item. Unlike the importance rating, the expertise rating does not change as a result of the iterative process. Once a participant has assigned an expertise rating to a particular data item he is unlikely to change it unless a reappraisal reveals that the rating was initially in error.

As an example, in the PFDS design effort, there were participants who had a great deal of experience in the area of asphalt pavements and very little experience in the area of concrete pavements. These individuals would rate their expertise high on the data items dealing with asphalt pavements and low on the data items dealing with concrete pavements. A similar situation existed in regard to functional positions. The maintenance foremen rated their expertise high on maintenance related data items, but low on design related items.

A data base design parameter of major importance in terms of the success of a system, is the determination of who is going to supply the data. As will be discussed shortly in another section of this chapter, initial presentations were made to twenty-five separate groups of the Texas Highway Department (THD) employees who were to participate in the Delphi project to design the PFDS data base. Almost invariably at the beginning of these presentations, one or more of the participants would inquire as to who was going to supply the data for the system. These questions are a minor indication of the widespread concern, amongst the users of data base systems, regarding the determination of who will be responsible for supplying the data.

In the general case, this concern could stem from a variety of causes. The requirement of having to supply a particular set of data items could be viewed as the imposition of an additional burden on an already heavy work load. Past experience with having to perform paperwork, where the benefits were intangible, not immediately apparent, and only indirectly related to the accomplishment of immediate work objectives, may tend to lessen an employee's enthusiasm for supplying additional data. Kanter comments that "in a highly decentralized organization where divisions are autonomous, the centralization of data in one central file can represent a serious obstacle. The divisions are skeptical about the information they submit; they wonder how it is going to be used" (Ref 51, p 63). These and many other possible problems could be reflected in the potential users concern over who is to supply the data.

In the PFDS presentations, the reply, "You, the potential users and suppliers, will determine who the suppliers of the data items will be," was always well received. Thus, it is theorized that the actual data capture process will be facilitated by allowing the potential users and suppliers to jointly participate in the determination of who will be responsible for supplying particular data items. It has been previously pointed out that group consideration in this type of situation is likely to lead to a more accurate assessment than could be made by a single individual. Furthermore, in addition to obtaining a more accurate determination of the potential suppliers than could be developed by a systems analyst, the act of participating in the determination process is theorized to lessen the potential suppliers' resentment toward the imposition of an additional work load. It should be considerably easier for the supplier to accept such a determination from a group of his peers with whom he has participated than it would be for him to accept a similar determination in the form of an apparent fiat from a systems analyst acting in a staff capacity.

Up until this point in the Chapter a general class of data base design information, which the potential users are capable of determining through a Delphi type methodology, has been demonstrated by the use of examples from the actual application of the technique to the design of the PFDS data base. This general class of information encompasses those types of information with which the potential user is in some way familiar. This familiarity might come from expertise in the area covered by particular data items, or it may come from areas of concern the potential user might have. However, it should be noted in the next two paragraphs, that during the PFDS project where the participants were inexperienced in data base concepts, an attempt to extend the Delphi methodology into the area of unfamiliar technical questions met with failure.

A shakedown of the Delphi process was run on a test group of 24 subjects selected from the THD and the Center for Highway Research (CFHR). The purpose of this test was to determine the feasibility of a Delphi methodology for data base design and to validate the attitude scale as discussed in Chapter 5. During this test the participants were required to provide and evaluate the information discussed above. In addition an attempt was made to have the participants rate the data items on the technical question of whether the item should be a key or non-key item.

In the presentation to the test group, it was explained that the key designation on a data item causes an inverted file to be constructed for that item; and the inverted file concept was then covered in detail. Numerous questions were raised during the presentation; and subsequent analysis of the participant's responses and interviews with them revealed that the concept was not understood in enough detail to allow intelligent decisions on the key/non-key question. It was concluded that, at least in the case of a new application where the potential users are unfamiliar with data base concepts, technical questions cannot be covered in the limited time normally available for a presentation on the Delphi method.

Delphi Procedures

A set of procedures was developed in the PFDS project to process the potential users' responses in regard to the above enumerated types of data base design information. A discussion of these procedures will help to clarify the methodology; however, before proceeding it is necessary to point out that these procedures have not been experimentally verified as being an optimal set. The purpose of the discussion, just as in the previous section on the types of information, is to demonstrate a functional class of procedures that can be generalized to a wide range of data base design problems. The aim is not to specify a rigid technique in great detail, but rather to present a methodology that can be readily adapted by other data base designers. Thus, the procedures that were utilized in the PFDS experiment are discussed along with some general suggestions in order to illustrate one way in which the Delphi methodology might be applied to a general data base design problem.

In general it is suggested that the group of participants who are to take part in the Delphi process be comprised of individuals from all functional areas and divisions within the organization. It is felt that widespread participation on the part of the potential users will help to more rapidly diffuse knowledge of the system and promote a greater degree of group acceptance. For example, in the PFDS case 241 potential users comprised of individuals from all 25 Districts, the Houston-Urban Office, Austin Headquarters Divisions, the CFHR, and Texas Transportation Institute (TTI) took part in the data base design effort. The objective in the selection process was to balance the proportional representation according to the number of potential users in each District, Division, or research unit. In addition the representation was also balanced according to the proportionate number of potential users involved in each functional area such as design, maintenance, and research. It is estimated that in the PFDS case approximately a fifth of the potential users took part in the data base design project.

After the participant identification phase has been completed a presentation should be made to the potential users who have been selected to participate in the Delphi process. Depending on the prior knowledge of the participants, the presentation should cover such subjects as a description of the proposed system, its objectives, basic data base concepts, and the procedures for the Delphi process of data base design. At the end of the presentation, an instruction booklet should be left with each of the participants along with the request that they send their initial submission of data items in to the administrator within a certain length of time. As an example, a copy of the instruction booklet used in the PFDS data base design project is included in Appendix A. Because of the geographically dispersed locations of the THD District offices, 25 separate presentations were required in the PFDS case. The PFDS presentations were also used for the administration of the measurement instruments required by the experimental design described in the next chapter.

As the initial submissions of data items are received from the participants, it will be discovered that many of the data items are duplicates of items already submitted by other participants. It is suggested that this situation be handled by compiling a non-redundant master list of data item descriptors. A unique item number is assigned to each of the original items added to the master list. Thus, an item number from the master list can be assigned to each data item descriptor on a participant's initial input form. After the initial input forms have been received from all participants, a completed master list of non-redundant items exists; and each data item descriptor on every participant's initial input form contains an item number that matches an item number on the master list of data item descriptors.

It should be noted that the absolute elimination of redundancy in the master list is not required, although it may be desirable. For example, in the PFDS project the administrator was unfamiliar with pavement terminology; and as a result, he was only able to eliminate redundant items where the descriptors contained similar wording. Redundant descriptors that contained different words describing essentially the same data item were not eliminated. It is possible to administer a Delphi process for data base design without being familiar with the technical questions involved. As the Delphi process progresses the redundancies are discovered and identified by the participants who have been selected from experts in the technical field under consideration. The information on redundancies that is supplied by the participants can be used to overcome the bimodal convergence that is likely to take place when two separate descriptors describing the same data item are present. The procedures for handling this occurrence are discussed at the end of this section after the necessary background on the importance and expertise ratings have been presented.

It is suggested that the participants be asked to indicate their importance and expertise ratings on each data item by using a 0.0 to 5.0 scale, with zero indicating absolutely no perceived importance or expertise with respect to the given item. Brief phrases describing the major steps in the scales, i.e. 0.0, 1.0, 2.0, etc, should be provided as rough guidelines for the participants. The guidelines for the scales used in the PFDS project can be found in the instruction booklet in Appendix A.

In the PFDS project an average of the importance ratings, weighted by the expertise ratings, was determined for each data item. That is

$$A^i = \frac{\sum_{j=1}^{n} I_j^i E_j^i}{\sum_{j=1}^{n} E_j^i}$$

where: I_j^i = individual j's importance rating for item i.

E_j^i = individual j's self appraisal of his expertise in regard to item i.

n = number in group.

This average on each data item was fed back to every member of the group until convergence was achieved. An estimate of the group's movement toward convergence was obtained, after each iteration, from the variance of the individual importance ratings about the average importance rating. That is

$$V^i = \frac{\sum_{j=1}^{n} (A^i - I_j^i)^2}{n-1}$$

The variance not only provides a means for determining when convergence has been achieved, but it can also be used to speed convergence by offering a means for deciding which items are important enough to be returned to the participants after each iteration. In order to speed convergence by eliminating unimportant data, the data items from the group are rank ordered on A^i. Those items that have a low A^i and a low variance of I_j^i about A^i, i.e. those items that are uniformly perceived to be unimportant, are not returned to the participants after every participant has had an opportunity to observe each item at least once. Although this feature is present in the generalized computer program that was used to process the information flows for the PFDS data base design project, it was not used. All data items were returned to the PFDS participants until convergence on all items was achieved.

The problem of bimodal convergence, that is likely to occur when redundant data items are present, can be overcome by using the information on redundancies that is supplied by the participants. The participants should be instructed to give the redundant data items they least prefer a 0.0 importance rating and to give the item they prefer most in the redundancy a regular importance rating. After convergence has been achieved and the redundancies have been identified, e.g. item 37 the same as item 103, then the importance ratings on the redundant items can be combined; and the items in a redundancy that are rated least in regard to importance can be eliminated. If each one of the participants has followed the instructions explicitly and has been successful in identifying all redundancies, then the importance rating of the remaining item, i.e. the most importantly rated item in a redundancy, can be obtained by summing the importance ratings of all items in the redundancy. Since it is not likely that all participants will be able to correctly identify all redundancies, it is suggested that a pass through the data item list of each participant be made. During this pass the importance ratings of all items in a redundancy, other than the item in the redundancy with the highest expertise rating, should be set to 0.0 and all expertise ratings in the redundancy should be set to the value of the highest expertise rating before performing the summation process. This procedure allows the retention of the redundant data item that the group most prefers and provides for the assignment of the correct importance rating to it.

A table which relates code numbers to suppliers of data items should be established in order to provide a method whereby the potential users and suppliers can determine who will be responsible for supplying particular data items. The supplier codes used in the PFDS data base design project are shown in Table 1 of the instructions which are included in Appendix A. The PFDS participants assigned one of the supplier codes to each data item that they submitted, and they also evaluated the supplier codes on all data items derived by the group. The evaluation process took place through the mechanism of feeding back the mode, or most frequently appearing supplier code, on each item to all participants in the group. The participants were thus able to indicate their agreement or disagreement with any supplier for a particular data item on each iteration. Convergence was found to take place on this value just as it did on the importance rating, although initially there was widespread disagreement on the suppliers of certain data items in the PFDS project.

Delphi Computer Program

A generalized computer program, for processing the information flows and implementing the procedures involved in a Delphi type data base design effort, was developed as a part of the PFDS project. A copy of this program, which automates much of the information processing required, is included in Appendix B. The program requires as input the master list of data item descriptors, that was previously discussed, and input from each of the participants on each of the data items. The program outputs summary statistics for the administrator and letters to each of the group members at the end of each iteration. A description of the application of a program of this type to data base design problems will help to further clarify the methodology. Examples from the PFDS project are provided in the discussion.

As the initial input is received from the participants, each original data item descriptor is assigned a unique item number; and a file, which comprises the master list of data item descriptors, is developed. The participants' data, which consists of an importance rating, an expertise rating, and a who supplies code, can then be entered in terms of an item number. After all of the initial input forms have been received, the data from the group is processed. The weighted average of the importance rating and the mode of the who supplies code are calculated. The administrator has the option of either receiving just a summary printout, which ranks the data items on the average importance rating and presents the variance on each item, or of also obtaining immediately the letters which communicate the results to the members of the group. The first option is provided in order to allow the administrator to truncate data items, that are uniformly perceived to be of low importance, from the list before printing the communications for the group.

The printout that communicates the results compiled from the group is mailed to each participant in the group who then indicates any disagreement he may have, regarding any piece of information, directly on the printout. A sample copy of a Delphi communication is presented in Figure 6. This hypothetical printout has been marked up by the participant, and it is ready to be returned to the administrator as the participant's input to the second iteration. When the participant first receives the printout there

DELPHI COMMUNICATION
PLEASE RETURN WITHIN FIVE DAYS

ROBERT J. MURPHY
SUPERVISING DESIGN ENGINEER
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INDIVIDUAL NUMBER 1 ITERATION NUMBER 1

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
5	3.0	.3	10	NUMBER OF LANES
6	3.2	1.0	10	LANE WIDTH
9	4.5	2.0	10	SUBGRADE SOIL TYPE
12	5.0	2.7	5	ANNUAL AVERAGE RAINFALL
14	4.0	2.3	5	ANNUAL AVERAGE TEMPERATURE
15	~~3.0~~ 4.2	2.5	10	MATERIAL TYPE FOR EA LAYER
16	4.5	2.5	10	LAYER NUMBER
17	1.5	2.0	~~10~~ 8	COST OF SUBGRADE PREPARATION/LANE MILE
	4.0	3.0	10	Layer Thickness

Fig 6. Sample Delphi communication.

are normally blank spaces in the expertise column. This indicates items that were submitted by other members of the group and which have not yet been reviewed by the participant to whom the printout is addressed. The participant fills in the blank expertise spaces with his expertise rating on the particular items. In the example of Figure 6, items 9, 12, 14, and 17 originally contained blank expertise spaces. Although the expertise ratings are the individual's expertise ratings, the importance ratings and the who supplies codes reflect a group average. The participant may indicate his disagreement with the group on any piece of information by crossing out the questionable value and writing his opinion out to the side. The participant is also allowed to enter new data item descriptors directly on the printout. The process is repeated until convergence is achieved. Copies of the converged printouts from two actual groups that participated in the PFDS project are included in Appendix C.

A computer program automates the printing of the letters and allows all corrections to be made directly on the printout. As each iteration is processed, the participants' unmodified input for the succeeding iteration can be output to either magnetic files or punched cards; and the updating process can thus be carried out either interactively or manually. A program of this type allows a single administrator, with only keypunch assistance, to process the input from a large number of participants.

Since the number of significant figures required in the importance rating, expertise rating, and who supplies code is small, it is possible to pack the value of one of these variables for several participants into a single computer word. Because of the nature of the problem, the code required for the packing and unpacking operations is relatively efficient. The program in Appendix B, which was used to process the information flows associated with the PFDS project, utilizes the packing principle.

PFDS Project

The PFDS data base design effort began with 241 potential participants attending the presentation. A control group of 27 individuals, the purpose of which will be discussed in the next chapter, was randomly selected from the larger group. The control group attended only the first half of the presentation, which dealt with a description of the PFDS system and its objectives. The control group did not participate in the Delphi process to design the data base. Out of the remaining 214 potential participants 208 submitted their initial input forms for the first iteration as requested in the presentation. These 208 participants were assigned to 20 Delphi groups of 10 individuals each and to one Delphi group composed of eight individuals. The criteria used in the group assignment process will also be discussed in the next chapter. At the start of the second iteration four participants had failed, for various reasons, to return their printouts; and at the start of the third iteration two participants were dropped from the process because of retirement and a major illness. By the end of the third iteration all 21 groups had converged and the process was terminated.

Because of the geographically dispersed locations of the participants, it was necessary to use the mail both ways in all communications during the process. It required approximately four weeks to turn around each iteration, and a total of approximately three months to run the process to convergence.

The low drop out rate, of approximately six percent over the entire three month period, is viewed as being a good indication of the degree of satisfaction that the participants found in the process. This is especially significant in view of the fact that a third of the drops occurred because of unavoidable problems such as a participant leaving the country, major illnesses, and retirement. It is also interesting to note that, when one other retiree and two participants who also underwent surgery were given the opportunity to drop, they insisted on remaining in the process. In addition, two of the dropouts went ahead and submitted their corrected printouts after the next iteration was started, even though they had been instructed that their input was no longer required since it was too late to incorporate their input with the groups'.

The PFDS master list of data descriptors covered 1310 data items at the time convergence was achieved. However, not all of these data descriptors described unique data items since the redundancies had not been removed from this list. The twenty-one groups converged separately on data lists that ranged in length from 89 to 293 data items. The reason for the apparent discrepancy in the length of the lists has to do with the way the groups were structured relative to cognitive style. The significance of this length difference will become clearer in the following chapters as the cognitive style experiment is described.

There were no indications, other than the key/non-key problem which occurred in the test, that the PFDS participants had any difficulty whatsoever in supplying and evaluating the information that was requested. The standard indicators of a smoothly functioning Delphi process, such as individuals reconsidering their opinion in light of the group response and movement toward convergence, were all present in the PFDS project. The project progressed just as expected except for the speed with which the printouts were returned. Since the participants were requested to return the printout within five days of receipt, it had been initially estimated that only two weeks would be necessary to complete an iteration instead of the four weeks actually required. Data was kept regarding the speed with which the printouts were returned, and an interesting relationship between the participants' cognitive styles and their speed of return was uncovered. This relationship is discussed in detail in Chapter 7. Another observation on the speed of return was that the early returners almost always returned the printout early and the late returners almost always returned the printout late. No correlation was found between the speed of return and the attitude of the participants.

In order to proportionally distribute the representation of the potential users in the PFDS project according to their function in the THD, four basic categories were established: 1) Administrative Level Personnel (14), 2) Other Engineers from District Headquarters (31), 3) Engineers from Residencies (30), and 4) Maintenance Construction Supervisors (25). The numbers in parentheses indicate the approximate relative percentage of participation from each of the four functional categories. The experimental design which is described in the next chapter required that the 21 groups be structured to a great extent along other dimensions; however, where possible an attempt was made to maintain an even balance of individuals from each of the four categories between the groups.

Since 21 separate Delphi groups were used in the PFDS project, a method of combining the results from the individual groups was required. The assumption was made that all groups possessed approximately the same level of composite expertise on any particular data item. The assumption appears to be valid, since within the constraints of the experimental design an attempt was made to distribute individuals with the same function evenly throughout the groups. The mean of the importance rating for each data item was calculated by using all groups that converged on that particular item, e.g. if the converged data lists of five out of the 21 groups contained a particular data item, then the mean importance rating of the five groups was calculated. The master list of data items was then rank ordered on the mean importance rating. The descriptors for the data items were output in their order of importance along with the mean importance rating, the number of groups considering the item, and the range of the importance ratings making up the mean.

The results from this output were used to decide which data items should be included in the data base. If the mean importance rating derived from a large number of groups was high and the range about the mean small, then that particular data item was definitely included in the data base. Similarly, if the mean importance rating derived from a large number of groups was small and the range about the mean was small, then the item was excluded from the data base. The items that were not clearly defined by this set of criteria were set aside for further consideration and analysis by a systems analyst.

The PFDS project was successful in its purpose of generating a large number of data items and bringing about a consensus of opinion amongst the potential users as to the relative importance of the various items. It provided data that could have been generated by a systems analyst only through massive interviews and numerous meetings, if at all. Thus, a systems analyst approach to developing the same amount and quality of information regarding potential data items, would be a practically impossible task in a decentralized and highly disbursed organization such as the THD.

The geographically disbursed nature of the 25 Districts in the THD leads to another problem that was overcome through the application of the Delphi methodology to the design of the PFDS data base. Because of their geographic separation, the Districts sustain widely varying terrain, climactic, and traffic conditions. The variance in these factors contributes to widely varying data needs amongst the Districts. However, Delphi provided a means whereby the opinions and data needs, of potential users from all of the Districts, were integrated into a single data base design.

Summary

It was found in the application of a Delphi methodology to the design of the PFDS data base that the potential users of the system are capable of supplying and evaluating a certain class of information that is helpful in the design of the data base. This class of information includes descriptors for data items the potential users perceive as being important, a rating of the degree of importance of each data item, a self appraisal of their expertise in regard to each data item, and their opinions as to who should be responsible for supplying the data for each item. Another class of information, dealing with technical considerations, was found to be more difficult to obtain from the potential users of PFDS who were initially unfamiliar with data base concepts.

Procedures for administering a Delphi methodology for data base design were discussed; and the methods used to calculate the averages, that were fed back to the participants during the PFDS project, were covered in the discussion. A generalized computer program to process the information flows associated with the procedures was described.

Throughout the chapter the emphasis was placed on imparting the philosophy behind the Delphi methodology for data base design, rather than prescribing a specific set of techniques in great detail. Although the specific procedures appear to be generalizable to a variety of data base design siutuations, it is felt that the greatest benefit is to be derived from an understanding of the concepts behind the methodology.

Examples, taken from the application of the methodology to the design of the PFDS data base, were used throughout the chapter to illustrate the theoretical concepts. Finally, salient aspects, of the application of the Delphi methodology in the PFDS project, were presented in order to provide the reader with a feeling for the application of the methodology in an actual data base design situation.

CHAPTER 4. RESEARCH DESIGN

The Delphi methodology, that was reviewed in the preceding chapter, not only proves to be an attractive method for data base design; but it also offers a research vehicle through which the effects of some personal characteristics of the potential users can be investigated. Cognitive style, a personal characteristic of decision makers, has been identified in the literature as having possible implications for the design of information systems. The impact of cognitive style on the design of data bases is amenable to analysis through the Delphi methodology; and this chapter examines the cognitive style research scheme that was executed during the Delphi project to design the PFDS data base. The hypotheses underlying the research effort are presented, and the experimental design that was developed to test these hypotheses is described.

Hypotheses

The fact that analytical individuals have been found to be more adept than global individuals at articulating the reasons and specifying the data behind their decisions leads to the speculation that the cognitive style variable is likely to be a factor in any attempt to have the potential users of a data base participate in its design. One major concern is the viability of the Delphi method as a means whereby the global individual can participate in the design process without being overwhelmed or frustrated by the more profuse output of the analytical type. It is theorized that the isolation of participants in groups, where interaction only takes place among individuals with a particular type of cognitive style, might be a means of overcoming this problem. Another important concern, in considering the possible adoption of a Delphi methodology, pertains to the potential user's attitude toward the system before and after he has participated in the design process. These and other potential concerns led to the formulation of the following four hypotheses regarding the influence of cognitive style and the effect of user attitude in the Delphi methodology for data base design.

Hypothesis 1:

In the initial round of the Delphi process, the number of elementary data items submitted by participants will be significantly correlated with their cognitive style.

Hypothesis 2:

Three distinct sets of Delphi groups; the first composed of more analytical participants, the second composed of more global participants, and the third composed of participants falling in between the global and analytical extremes; will converge to data base designs that are significantly different.

Hypothesis 3:

A set of Delphi groups composed of participants with least favorable attitude scores will converge to a design that is significantly different from the design obtained by groups with similar cognitive style scores but higher attitude scores. In other words, an unfavorable attitude score moderates the cognitive style effect.

Hypothesis 4:

The attitude scores of all groups will improve as a result of participation in the Delphi process.

These hypotheses were tested as a part of the Delphi project to develop the data base design for PFDS. However, the experimental design that was used to examine the validity of the hypotheses is presented before undertaking, in subsequent chapters, the discussion of the results from the statistical tests.

Experimental Design

In addition to the 24 test subjects who were involved in the preliminary shakedown of the methodology, 241 potential users actually participated in the PFDS data base design project; and the sample used to test the foregoing hypotheses was developed from the 241 participants who took part in the PFDS project. The initial selection of the participants was accomplished by submitting a request to the heads of the Texas Highway Department (THD) Districts and Divisions asking that they identify a list of participants for the project. It was suggested that their selection consist of specified numbers of individuals from each of the four functional areas outlined in the discussion of the PFDS project in Chapter 3. The numbers suggested were based on the proportion of individuals normally working in each of the four areas and in each of the Districts or Divisions. A similar procedure was followed in regard to the seven individuals from the Center for Highway Research (CFHR) and Texas Transportation Institute (TTI). The initial request was for 230 participants; however, some District heads requested that extra individuals be allowed to participate, and 241 people ended up attending the presentation to initiate the Delphi project. The fact that the District and Division heads selected the individuals to participate in the process, which resulted in the lack of a random sample, was not felt to be a significant deterrent to the research design since the sample was calibrated and assigned according to test scores.

Each of the 241 individuals that were selected from the THD, CFHR, and TTI, as was described in the preceding paragraph, attended one of the 25 presentations that were held in District offices throughout the state. In the first half of these presentations the participants received instruction in the objectives of the PFDS system and elementary data base concepts. They were informed that they had been selected to take part in a project to design the data base for the PFDS system. Then scales for the measurement of the participants' cognitive styles and their attitudes toward PFDS and their participation in its development were administered. Completion of the two tests ended the first half of the presentations and the participants were given a coffee break.

From the selected sample of 241 potential PFDS users that was drawn from the THD, CFHR, and TTI, as described above, a randomly selected sample of 30 individuals was designated as the first control group. During the coffee break, which followed the first half of the presentations, the individuals designated as part of the control group would be approached and asked to volunteer to act as control subjects. They were instructed that they would have nothing else to do with the project until the rest of the group had completed the task of designing the PFDS data base, and they were informed that they would then be asked to retake the attitude scale or Opinion Survey, as it is titled. All of the subjects approached agreed to this request, and they did not attend the second half of the presentation.

During the coffee break of the last presentation it was impossible to approach the control subjects, and the second half of the presentation began with three of the designated control subjects present. Since the three subjects had received some exposure to the Delphi concept before the error was discovered, it was decided to allow them to act as regular participants and to proceed with a first control group composed of only 27 subjects. The purpose of the first control group was to serve as a base point for any attitude change that might take place, on the part of the participants, as a result of being involved in the process of designing the PFDS data base.

The second half of the presentation concentrated on providing the participants with a background on Delphi and the procedures for applying the technique to the design of the PFDS data base. A description of the technique was presented, and the origin of the method was discussed. Examples of the application of Delphi in both government and private business were provided, and some of the experiments conducted by Rand were brought to the group's attention. Examples of the types of data items that the group was expected to provide for the PFDS data base were covered, and the initial input forms the participants were to use in submitting their data items were displayed. A simulated run through the process was described by using the example from the sample Delphi communication that was presented in Figure 6. After the mechanics of the process were covered, the participants were given the instruction booklet, that appears in Appendix A, along with several blank initial input forms. They were requested to complete these forms and return them to the administrator within five days, if possible. This request was an attempt to assure everyone, from all of the 25 separate presentations, approximately the same amount of time on each iteration of the project.

A final precaution was taken at the end of the presentation. As is standard in the Delphi Technique the participants were cautioned against talking with anyone about the project until its completion was announced by the administrator. The purpose of this measure was not only to maintain the integrity of the Delphi process by assuring that interaction took place only through the Delphi medium, but it was also used to maintain the integrity of the experimental design. Since the experimental groups were to be segregated according to their cognitive style, it was imperative that no unintended interaction take place across the groups. The caution to the groups regarding the integrity of the Delphi process thus served to accomplish both of these objectives without having to reveal the experimental aspect of the project.

The numerical scores, obtained from grading the cognitive style and attitude scales that were administered during the first half of the presentations, were used in assigning the participants to Delphi groups. Details concerning the selection of the cognitive style scale and the construction of the attitude scale are presented in the next chapter. Before applying the numerical scores obtained from the scales, a second control group of 40 subjects was randomly selected from the first 200 active Delphi participants who submitted their initial input forms. The last eight active participants to submit initial input forms were assigned to a group that did not take part in the cognitive style research effort. Then assignment of the remaining 160 active subjects was made to four distinct sets of major Delphi groupings which were named; Analytical, Global, Mixed, and Attitude. This assignment was made without the subjects' knowledge and before Delphi feedback was given to the participants to begin the second round of the design. The 40 subjects with the least favorable attitude scores were assigned to the attitude group. The remaining 120 subjects were assigned by rank ordering their cognitive style scores. The 40 subjects with the highest cognitive style scores were assigned to the Analytical group; the 40 subjects with the lowest cognitive style scores were assigned to the Global group; and the 40 subjects in the middle of the cognitive style distribution were assigned to the Mixed group.

The sample assignment procedure is reiterated and graphically illustrated in Figure 7. Beginning at the upper left and moving to the lower right, 27 of the 241 subjects (*S*'s), who attended the presentations, were randomly selected for the first control group as was previously described. After receipt of 200 initial input forms, 40 of the subjects were randomly assigned to the second control group. The remaining 160 subjects were ranked according to their attitude scores, and the 40 subjects with the lowest attitude scores were assigned to the attitude group. The remaining 120 of the first 200 subjects to respond were then ranked according to their cognitive

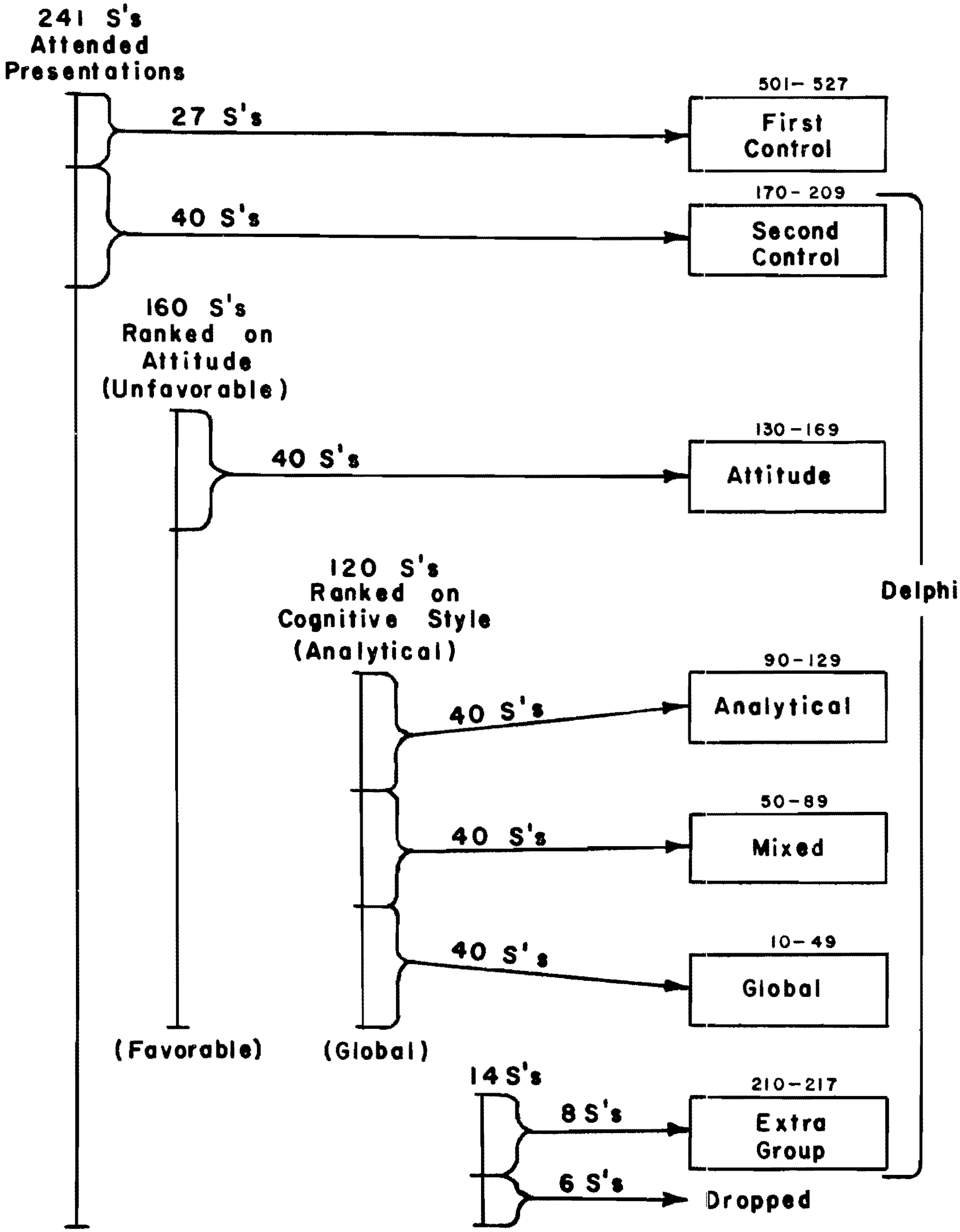

Fig 7. Sample assignment.

style scores. The 40 subjects in the analytical third of the cognitive style continuum were assigned to the Analytical group. The 40 subjects in the middle third of the continuum were assigned to the Mixed group, and the 40 subjects in the global third of the continuum were assigned to the Global group. Out of the remaining 14 subjects, eight submitted their initial input forms before the first iteration was begun, and together they were assigned to an extra Delphi group. The six subjects who did not respond in time were dropped from the process.

The purpose of the second Control group was to provide an observation as to how participants would respond when lumped together in Delphi groups without regard to cognitive style, and the Attitude group offered a means of determining how potential users with low attitudes toward a system are likely to perform in a Delphi process to design the system's data base. The first Control group and the six subjects who were dropped did not participate in the Delphi process, and although the extra group did participate in the Delphi process, they were not a part of the cognitive style experiment.

The five primary groups--Global, Mixed, Analytical, Attitude, and the second Control--were broken down into smaller Delphi groups in order to obtain a sufficient number of replications to support the statistical analysis of the hypotheses. In attempting to determine the number of individuals to assign to each Delphi group a trade-off was encountered. The larger the number of replications the more apparent would be any differences from the cognitive style effect. However, the larger the number of Delphi groups the smaller would be the group size; and a loss in accuracy and reliability would be suffered as a result. In order to resolve this trade-off, reference was made to Figures 3 and 4 in Chapter 2. In a Delphi group of seven participants, both the reliability and the accuracy is indicated by the figures to be fairly high; and seven is a common number of participants found in the Rand groups. It was decided that seven participants per group would be sufficient for the purposes of the PFDS project and the cognitive style experiment. Therefore, to overcome the effect of further drop outs and to be sure that the groups would contain at least seven participants at the time of convergence, it was felt that initially 10 subjects per Delphi group would be required. Thus, four groups of 10 subjects each were formed into actual Delphi groups within each of the five primary groups. This procedure resulted in the formation of 20 Delphi groups composed of 10 subjects each to participate in the cognitive style experiment.

Assignment of individuals to the four Delphi groups within each of the five primary groups was performed in such a manner as to make the four groups as homogeneous as possible. This was done in an attempt to overcome the effect of the small number of replications per treatment. All available information regarding the subjects, such as attitude scores, cognitive style scores, and departmental positions, were used in the homogenizing process. Individuals were assigned to the four groups so the mean and range of the attitude and cognitive style scores were approximately the same for each of the groups. The group assignments were also balanced in relation to the subjects' positions both functionally and locationally where possible. It was hoped that by balancing the four Delphi groups within each primary group the effect of variance due to variables other than attitude or cognitive style would be minimized.

Computer processing was required in order to accommodate the large volume of information transfer associated with the PFDS data base design project, and a numbering scheme for the Delphi groups was established to facilitate this processing. Each individual participating in the experiment was assigned a number which expressed his position in regard to each of the five primary groups and also in regard to his Delphi group. These numbers for the 200 subjects ranged from 10 through 209. The last digit on the right expressed the individuals's position in his Delphi group, while the digit or digits to the left of the right most digit identified which one of the 20 Delphi groups the subject was assigned to. Groups 1 through 4 were Global groups, 5 through 8 were Mixed groups, 9 through 12 were Analytical groups, 13 through 16 were Attitude groups, and 17 through 20 were Control groups. Thus, individual number 10 identified the first individual in the first Global group; and individual number 209 identified the last individual in the last Control group. The eight participants in the extra group were assigned individual numbers 210 through 217, and the 27 subjects in the first control group were assigned individual numbers 501 through 527. The individual numbers for the various primary groups appear on the boxes indicating these groups in Figure 7.

The Delphi process was independently run to convergence in three iterations for each of the 21 groups. During the process six participants dropped out of five Delphi groups for various reasons that were discussed in Chapter 3. Therefore, the lowest number of participants in any one group at convergence was eight. This figure is more than was required, since only seven participants were deemed necessary, in each Delphi group at convergence, to maintain the desired accuracy and reliability. Communication with the participants was conducted by mail after the initial presentation except for a limited number of telephone calls placed either by a participant to pose a question or by the administrator to check into late replys. After convergence of the data base design had been achieved in each of the 21 groups, the attitude scale was readministered by mail to all of the participants who were still active.

One of the primary objectives, in the development of the experimental design for the cognitive style phase of the experiment, was the minimization of the possibility of introducing experimenter bias into the process. This objective was not adherred to or even considered desirable in the Delphi evaluation phase of the project. In the Delphi evaluation phase the administrator made every effort to conduct the Delphi project in the best possible manner. The objective was to determine if a Delphi methodology for data base design could be applied successfully in an actual application. Even though the possibility does exist that another administrator could conceivably present the method in such a manner as to cause its failure, this fact is not considered to be relevant. However, the validity of the cognitive style results is inextricably linked to the experimental design; therefore, both the strongest and the weakest aspects of the design, in regard to the introduction of experimenter bias, are discussed.

The minimization of the reactive effect to the measurement instruments is felt to be the strongest aspect of the experimental design. All, but one of the 200 participants, were completely unaware of the cognitive style experiment that was being conducted as a part of the PFDS project. The fact that an experimental Delphi type methodology was being used in the design of the PFDS data base was the extent of the participants' knowledge concerning the nature of the project. The administration of the cognitive style scale was explained during the presentation as being a method for determining the amount of detail the participants would prefer in the output from the system. The fact that the cognitive style score would also be used as a basis for assignment to Delphi groups was not mentioned, and there was no indication during the experiment that any of the participants guessed this purpose. Likewise, the attitude scale was administered under the title Opinion Survey; and its purpose was explained as a method for obtaining the participants' opinions regarding the system before and after they were familiar with the data contents of the data base. It was explained that these opinions would be used in evaluating the decision of whether or not to proceed with implementation of the system. Since the cognitive style portion of the experiment was not apparent to the participants, it is unlikely that the common experimental effect, of the subjects trying to please the experimenter, was present in regard to the cognitive style phase of the experiment. In addition, further mitigation of possible reactive effects was felt to take place as a result of the Delphi methodology. The Delphi requirement of having to agree as a group is believed to suppress some of the reactive tendencies that might be found when dealing with individuals. It is difficult to imagine an unconscious conspiracy on the part of the group to adopt, for example, a Global response set and to play out the Global role as a group.

The weakest aspect of the experimental design derived from the necessity of the administrator having to grade the cognitive style scales and also having to develop the master list of data items. It may be theoretically possible, although practically impossible in a highly complex situation such as PFDS, that the administrator could have unconsciously memorized the 200 cognitive style scores and then unconsciously tried to structure the 1300 data item master list in order to produce a cognitive style effect in the experiment. It was anticipated that a few complaints might be registered by participants because of the slight changes in the wording of data items that was necessary in order to eliminate redundancy. Thus, evidence that the above mentioned experimenter effect did not take place in the PFDS experiment can be found in the fact that only one participant registered a mild complaint that the returned output did not exactly match his initial input.

Summary

Four major hypotheses concerning the influence of cognitive style and the attitude of potential users in a Delphi methodology for data base design were formulated, and an experimental design which was developed to test these hypotheses was presented. The procedures, for sample selection and for utilization of the scores obtained from attitude and cognitive style scales in assigning participants to Delphi groups, were discussed. It was pointed out that the criteria used for the selection of the cognitive style scale and the construction of the attitude scale would be covered in the next chapter. A numbering system which was devised to facilitate the computer processing of the participants' replys was also described. Finally some strengths and weaknesses of the experimental design were presented.

CHAPTER 5. MEASUREMENT INSTRUMENTS

Methods for numerically scoring the behavioral dimensions of cognitive style and attitude are necessary in order to implement the experimental design outlined in Chapter 4. Therefore, this chapter describes the instruments that were selected and developed to numerically assess the cognitive style and attitude characteristics of the individual participants. The first section of the chapter discusses a commonly used instrument, for measuring cognitive style, that was selected for use in the PFDS data base design project. The second section deals with the steps that were followed in order to modify a recently validated attitude scale to make it applicable to the PFDS effort in the THD.

Hidden Figures Test

The work of McKenney, Keen, and others, which was summarized in Chapter 2, Review of the Literature, has been directed toward the development of a comprehensive model of cognitive style. This author views the McKenney, et al work as holding forth the possibility of eventually culminating in a sound model for use in cognitive style research. However, the fact that the model utilizes twelve written tests requiring one-and-a-half hours coupled with the fact that the model is still in the preliminary stages of development mitigated any enthusiasm for its adoption in the PFDS project. The more traditional views of cognitive style, which have received wide recognition in the literature, were adherred to in the search for a suitable cognitive style instrument.

As was also discussed in Chapter 2, the concept of cognitive style is characterized by many diverse behavioral dimensions such as perception, adaptation, intellect, and personality. In our present rudimentary stage of understanding there has been a tendency to concentrate on particular aspects of cognitive style; and one all encompassing measure has not been developed, although tests have been perfected which address a specific dimension of the concept. Therefore, "for research purposes cognitive style has been operationally defined in terms of the testing situations; that is, instruments, used to measure it" (Ref 32, p 8).

Several criteria were employed in the process of selecting a cognitive style dimension and its associated instrument for use in the PFDS project. First, it was considered essential that the instrument be consistent with the nature of the task that the participants were being asked to perform, i.e. articulate data items used in their decision making experience. Secondly, it was highly preferable that the instrument be a standardized test developed by experienced testing specialists. Finally, it was considered desirable that the test have a prior history of being employed in similar lines of research. Fortunately it was possible to locate an instrument that meets all of the above criteria.

The Hidden Figures Test (HFT), developed by the Educational Testing Service of Princeton, New Jersey, in 1963, is an adapted version of the original written test which was used by Witkin to determine a subject's ability to overcome an embedding contest. Educational Testing Service's designation *adapted version* indicates that the test is "*parallel* with the original test" (Ref 37, p 4), i.e. within measurement error measures the same variable. The work of Witkin and his associates, on the field dependence-field independence concept, represents the first and most extensive body of research in the cognitive style field. The concept has been examined in depth and widely reported in the literature. In this work Witkin has shown that the ability "to keep an item separate from a field or embedding context" is related to the field dependence-field independence or global-analytical concept (Ref 67, p 172). In addition it has been shown "that ability to break up an existing structure and the ability to structure an unstructured situation tend to go together" (Ref 67, p 175). In other words, the analytical subject is better able to impose structure on a field. Furthermore, the ability to articulate experience has been shown to be linked with analytical ability (Ref 67, p 176). Since the participants in the study were being asked to pull data items from an unstructured context, it was concluded that the HFT adequately meets the first criterion.

Educational Testing Service's extensive experience in test development and administration unequivocally satisfied the second criterion; therefore, attention was directed toward determining if similar research had been conducted with either the HFT or the parallel Embedded Figures Test used by Witkin. It was found that Doktor and Hamilton, in their study of the relationship between management reporting styles and cognitive style, employed the original Embedded Figures Test in their experiment (Ref 27, p 885). Thus the third criterion was also satisfied, and the HFT was selected for use in the PFDS data base design project.

The HFT is a multiple choice test which requires the subject to decide which one of five simple geometrical figures can be found in a more complex pattern. The manual for administering the HFT indicates that it tests "the ability to keep one or more definite configurations in mind so as to make identification in spite of perceptual distractions" (Ref 37, p 9). The test consists of two parts each with 16 items, and the subject is allowed 10 minutes to complete each part. The level of difficulty of the test is high and a wide variance in scores has been found.

The subject's cognitive style score is the number of right answers corrected for guessing by the following formula:

$$S = R - \frac{W}{4}$$

where S is the corrected score, R is the number of right answers, and W is the number of wrong answers. The higher the subject scores on the test the more analytical is his cognitive style. A copy of the directions for the HFT, which include two sample items, can be found in Appendix D.

Attitude Scale

A search of the literature failed to reveal the previous existence of a scale developed expressly for the purpose of measuring attitudes toward data base systems. In addition, when consideration was given to the possibility of developing a scale specifically for the purpose of the PFDS research effort, it was concluded that difficulty would be encountered because of the limited population to which the scale would be applied. It was conceivable that almost the entire population, concerned with PFDS within the THD, could have been contaminated by an attempt to develop a suitable attitude scale. Fortunately a generalized scale used to measure attitudes toward any one of a general class of OR/MS model referents was located.

The attitude scale recently validated by Schultz and Slevin for OR/MS model implementation was selected and modified for use in the experiment. This instrument was designed so that it would "be applicable to a variety of populations and a variety of innovations" (Ref 78, p 18). The instrument was pilot tested on 136 MBA students at the University of Pittsburgh and then field tested in a large heavy manufacturing company in the Pittsburgh area. The attitudes of 98 potential users of an MIS innovation, that was scheduled to be implemented in the company, were measured with the attitude scale. These attitude scores were found to be significantly correlated with an expressed intention to use the MIS innovation when it became operational.

The Schultz and Slevin instrument is based on the Likert summated ratings technique. In this method of attitude measurement the subjects are required to select any one of five categories: strongly disagree, disagree, uncertain, agree, or strongly agree to express their response to each statement in a set of statements. Although the original Schultz and Slevin scale consists primarily of favorable statements, it is traditional that the set of Likert statements be composed of two approximately equal classes of statements differentiated into favorable and unfavorable categories since "attitudes are learned predispositions to respond to a psychological object in a favorable or unfavorable way" (Ref 35, p 257). These categories are weighted such that the most favorable attitude will always have the highest positive value. In the favorable statements, the strongly agree response is assigned a weight of four, the agree response a weight of three, the undecided response a weight of two, the disagree response a weight of one, and the strongly disagree response a weight of zero. In the unfavorable statements, the scoring system is reversed, with the strongly disagree response being assigned the weight of four and the strongly agree response the zero weight. The subject's total attitude rating is then obtained by summating his scores from each of the individual statements in the set.

The Schultz and Slevin instrument originally consisted of 67 items; however, a factor analysis of the data obtained in both the pilot and field tests indicated that only 57 of the 67 Likert items loaded on seven factors, which were defined as:

1. Manager's job performance
2. Interpersonal relations
3. Changes resulting from model
4. Goal achievement and congruence
5. Support for the model
6. Client/researcher interface
7. Importance and urgency of results.

Schultz and Slevin feel that these factors "are consistent with previous empirical findings and meet a priori expectations." In addition, they feel that these factors "provide useful guide-lines for future research by allowing the investigator to focus on a small number of behavioral dimensions" (Ref 78, p 19).

In order to decide which of the 57 statements, that loaded on the seven behavioral dimensions, to include in the PFDS attitude scale, it was first necessary to gain a clear conception of the attitude variable toward which the PFDS scale was to be directed. Shaw and Wright state that

> As the attitudinal referent is conceived to be goal facilitating, it will be evaluated positively; it is evaluated negatively to the extent that it is conceived as inhibiting or interfering with goal attainment. . . . This affective, evaluative reaction will be more intense as the goal is more important to the conceiver (Ref 80, p 6).

This property of attitudes was selected as the first criterion for evaluating the suitability of the Schultz and Slevin items for inclusion in the PFDS attitude scale. It was assumed that the more PFDS is seen to facilitate the goals of the user the more favorably will he tend to view PFDS. In other words, statements were selected that appeared to have a direct relationship to the subject's personal or organizational goals.

A second criterion that was used in the selection of statements was the factor loadings associated with each of the 57 items. From those items that clearly reflected the goal relationship, the items with the highest loadings were selected. This two level selection process resulted in twenty-two of the Schultz and Slevin statements being included in the PFDS attitude scale. Ten of these statements came from the Job Performance dimension, four from the Goals dimension, two from the Support dimension, two from the Client/Researcher dimension, and four from the Urgency dimension. The two statements from the Client/Researcher dimension, along with three other statements developed by this author, were included in Part II of the PFDS scale which measures the subject's attitude toward his participation in the PFDS data base design. The remaining twenty statements from the other dimensions were used to make up Part I of the scale which deals with the subject's attitude toward PFDS itself.

Several of the Schultz and Slevin statements were altered slightly to better reflect the statements' pertinence to PFDS. In addition, since it was desirous of adhering to the traditional Likert framework of approximately one-half favorably worded and one-half unfavorably worded statements, ten of the Schultz and Slevin items had to be modified to take on a negative connotation. This was a precautionary measure to avoid the possibility of the subjects developing a response set to the questionnaire. After the statements were suitably reworded, their order of appearance in the PFDS scale was determined by a random assignment procedure. The two part, twenty-five item scale resulting from this process served as the starting point for further validation.

Although it was strongly felt that the discriminate selection of statements with the highest factor loadings from a previously validated scale would in itself result in an adequately valid and reliable scale for PFDS use, further validation procedures were employed as a check. Prior to utilizing the scale on the test group of 24 subjects, a crude approximation of validity and reliability was obtained by having a group of ten subjects adopt an attitude set toward PFDS before completing the questionnaire. Five of the subjects were instructed to adopt a favorable attitude set and the other five an unfavorable set. The mean score from the five favorable subjects was high (85.8) with a low standard deviation (6.9), and the mean score from the five unfavorable subjects was low (13.6) with a low standard deviation (7.3). Albeit crude, these findings indicate that the scale possesses a high degree of *construct validity*. As a by product of this preliminary testing it was discovered that one of the items was ambiguously worded, thereby allowing a correction to be made before administering the scale to the test group of 24 subjects.

In addition to the construct validity a *split-half* reliability was also run on the data obtained from the ten preliminary subjects. In the split-half method, the total number of statements is divided into two parts and each part is treated as a separate scale. The reliability measure is the correlation between the scores on the separate parts. Since a random assignment of statements had been previously made for the PFDS scale, it was decided that the even number statements would constitute one part and the odd number statements the other part. Denoting the correlation coefficient or reliability measure by ρ , it was found that $\rho = .98$ for the correlation between the odd and even halves. This correlation coefficient was the reliability for a scale only one-half as long as the scale actually used in the project; therefore, a method for estimating the reliability of the larger scale was required (Ref 84, p 87).

The Spearman-Brown Prophecy formula indicates the increase in reliability that can be expected as a function of the length of the scale. The revised reliability (ρ') is given for a scale that is n times longer than the original scale by the formula

$$\rho' = \frac{n\rho}{1 + (n-1)\rho}$$

In the case of the split-half method $n = 2$; and substitution of $\rho = .98$, which was calculated for the half scale, yielded a revised reliability estimate $\rho' = .99$. This very favorable result, although quite crude, prompted the decision to proceed with the use of the attitude scale for the test group.

A more refined *internal consistency* reliability estimate was obtained from the results of administering the scale to the test group of 24 subjects by the widely used Cronbach α method (Ref 84, p 89). In this method the reliability estimate α is calculated from the formula:

$$\alpha = \frac{n}{n-1}\left[1 - \frac{\sum_{i=1}^{n} \sigma_i^2}{\sigma_x^2}\right]$$

where n is the number of items in the scale, $\sum \sigma_i^2$ is the sum of the diagonal elements of the covariance matrix, and σ_x^2 is the variance of the total scale. This method offers a more powerful reliability estimate since it "examines the covariance among all of the items simultaneously rather than in a particular and arbitrary split" (Ref 84, p 87). Analysis of the results of the attitude scores of the test group yielded an α of .91.

Since the Cronbach α internal consistency reliability estimate was also found to be very favorable, it was concluded that the attitude scale was adequate for use in the PFDS project. A copy of the attitude scale is included in Appendix D under the title PFDS OPINION SURVEY.

Summary

The selection of an appropriate cognitive style dimension and its associated measurement instrument(s) was limited to those cognitive style concepts that have been reported in the literature and are widely recognized and accepted by workers in the field. The first and most extensive body of research in the cognitive style field is that related to Witkin's field dependence-field independence concept. Since this concept postulates a predisposition to behave in certain ways in situations closely related to the task that the participants were being asked to perform in designing the PFDS data base, the Hidden Figures Test (HFT), which is used in measuring this concept, was selected for numerically assessing the participants' cognitive style.

An attitude scale that had been previously validated for use in OR/MS model implementation was modified and tested for use in the PFDS project. During the testing phase the modified scale was found to have a very high internal consistency reliability; therefore, this modified attitude scale was adopted for use in the PFDS data base design project.

The two instruments offer a means for numerically scoring the experimental dimensions of cognitive style and attitude. Thus the scores obtained from administering the HFT and the attitude scale were used in statistically testing the hypotheses put forth in Chapter 4, Research Design. The results from the statistical tests of these hypotheses are discussed in the remaining chapters.

CHAPTER 6. COGNITIVE STYLE AND THE ARTICULATION OF DATA ITEMS

The first hypothesis in Chapter 4 postulates a relationship between a potential user's cognitive style and his ability to independently develop data items that he perceives as being important in a data base. In a Delphi methodology, the participant is initially faced with the task of extracting information from his experience, that deals with his past decisions or decisions that he anticipates in the future; and he is asked to supply this information in a specific form. The first section of this chapter examines the nature of this task in terms of the cognitive style concept and sets out the assumptions that led to the formulation of Hypothesis 1. Then, the second section of the chapter presents the results from the test of Hypothesis 1 that were obtained in the cognitive style experiment which was conducted as a part of the project to design the PFDS data base. The significance of the results are discussed in terms of the implications they hold for the PFDS cognitive style research effort.

Nature of the Task

In supplying data items for potential inclusion in a data base, the Delphi participant is called upon to identify types of information that he feels might be important in problem situations likely to confront him in the future. As was discussed in Chapter 1, if the variables and interrelationships amongst the variables in a problem situation are well defined, the need for a data base system, other than for archival purposes, is small. It is in ambiguous and complex problem situations that the need for a data base system is greatest. Thus, almost by definition, the participant in a Delphi type data base design project is faced with a complex ambiguous environment. Therefore, in accomplishing his task of supplying data items, the participant is required to differentiate and articulate the relevant elements of this complex stimulus. He is required to overcome the embedding context of the whole problem and to identify the parts of the problem that are pertinent to its solution. He must then restructure the elements he has identified in order to present them in the specified form.

Many of the various aspects of the task, that the participant is being required to perform when he is asked to supply potential data items, have been found to be related to the field-dependent/independent or global-analytical concept. In the review of the literature that was conducted in Chapter 2, it was shown that Witkin and his associates have found the global individual to be less adept at overcoming a dominant organization in his attempts to identify relevant discrete items within a complex field. In addition, the global individual has also been found to be less adept at structuring ambiguous stimuli. For example, global people require a relatively longer time to locate a familiar figure hidden in a complex design; and in the Rorschach inkblot test the global person is usually unable to impose organization on the stimulus material, which he usually perceives as vague and indefinite.

The Delphi participant is in essence being asked to identify the concepts underlying the particular problem for which the data base is being designed and to articulate these concepts in the form of relevant data items. A recent study by Davis and Klausmeier (Ref 23) investigated the relationship between a subject's performance on a standard concept identification task and his cognitive style as measured by the Hidden Figures Test. "An individual's cognitive style was found to influence his concept identification performance. Individuals identified as analytical on the Hidden Figures Test experienced little difficulty in identifying concepts while subjects (low analytic) who experienced difficulty in locating the simple figures in the Hidden Figures Test experienced considerable difficulty in concept identification. Individuals falling in the middle of the Hidden Figures Test distribution performed at an intermediate level of performance on the concept identification task" (Ref 23, p 427).

Peter Keen, whose work was also reviewed in Chapter 2, has attempted to relate cognitive style to individual decision making. He cautions that certain types of individuals, whom he characterizes as Intuitive, are unable to reconstruct the steps they follow in arriving at problem solutions because these steps are unknown to them. Therefore, Keen feels that the intuitive type simply cannot articulate the types of data they use in their decision making activities.

The considerations, enumerated above, led to the assumption that the cognitive style of participants is likely to be an influence on the number of data items they submit for the initial round of the Delphi process. It was assumed that the global type individual would be less likely to submit a large number of data items than the analytical type individual. These considerations and assumptions were used in the formulation of the hypothesis that, in the initial round of the Delphi process, the number of elementary data items submitted will be significantly correlated with the participants' cognitive style.

Correlation Found in PFDS Experiment

In the PFDS cognitive style experiment the subjects' cognitive styles along the global-analytical dimension were assessed with the Hidden Figures Test (HFT). The scores on the HFT ranged from -3 to 26 for the 241 participants in the project. A count was also taken of the number of data items each of the 208 active participants submitted for the first round of the Delphi process to design the PFDS data base. The number of items initially submitted ranged from 4 to 179 for the 208 active participants. The pertinent data, on the 241 participants in the PFDS project, is included in Appendix E. The first column of this data is the individual numbers that were described in the discussion of the sample assignment procedures in Chapter 4. The second column contains the HFT score for each individual, and the third column is the number of data items submitted by each of the participants for the first round. The other columns contain the prior and post Delphi attitude scores and the rankings of the participants in regard to their HFT and pre-attitude scores. The pre-attitude and post-attitude scores will be referred to in Chapter 8 when the effect of participation on the potential users' attitudes is reported. The places where blanks or zeros occur in the data, other than in the HFT scores, indicate that the participant dropped out of the process; and a rough indication of when the individual dropped can be obtained from the consideration of which scores are missing.

A correlation coefficient was computed between the HFT data contained in the second column and items submitted data contained in the third column. The correlation coefficient (r) obtained between the HFT scores and the data items submitted was .230; and this correlation was found to be significantly greater than zero at the α = .0005 level. Therefore, the coefficient of determination (r^2) equals .053, which indicates that approximately five and one-half percent of the factors contributing to the participants' performances on the HFT also contribute to their performances in submitting data items.

In the PFDS experiment the coefficient of determination is not only small, but as in all correlational analysis there is no firm evidence to support an inference that cognitive style accounts for even this small common factor that was found between the participants' performances on the HFT and their submittal of data items. For example, one rival hypothesis, although it is not viewed by this writer as being highly plausible, might be that intelligence accounts for both the HFT and data item submittal performances. Even though no attempt was made to control for IQ in the experiment, the credibility of this rival hypothesis is in doubt because all participants in the project held responsible positions and were selected with regard for their ability. However, the fact remains, it is conceivable that some plausible rival hypothesis may account for the common factor that was found. The significant positive correlation between HFT scores and data items submitted can only, at best, provide a possible indication that cognitive style accounts for both performances.

The significance of possibly accounting for only five and one-half percent of the variance in terms of cognitive style may, at first glance, appear to be minor; however, when viewed from the perspective of what could be expected, the findings take on an added significance for the PFDS cognitive style research effort. There are many probable sources, other than cognitive style, effecting the variance in the participants' submittal of data items. The amount of time each participant has available for the project and the participant's familiarity with the subject of the project probably have a great deal to do with the number of items he submits. For example, in the PFDS project, researchers who were intimately familiar with the PFDS concept appeared to be more likely to submit a large number of items independent of their cognitive style. In light of the fact that a large variance would ordinarily be expected in the submittal of data items, the correlation found in the PFDS cognitive style experiment appears to be a significant finding. The fact that a zero correlation was not present to disconfirm Hypothesis 1 provides a tentative favorable indication that the more extensive research conducted to test Hypothesis 2 might prove to be valuable. The results of the statistical tests of Hypotheses 2 and 3 are discussed in the next chapter.

Summary

The considerations and assumptions, leading to the formulation of the hypothesis that the number of elementary data items submitted by participants for the first round of the Delphi process will be significantly correlated with their cognitive style, were presented. The origin of these assumptions, in terms of the nature of the task as it is influenced by the cognitive style concept, was reviewed. In this review, it was shown that the global individual is less adept at overcoming a dominant organization in his attempts to identify relevant discrete items within a complex field. This cognitive style characteristic provided the foundation for the development of the hypothesis.

The small, positive, and significant correlation between HFT scores and data items submitted, which was found in the PFDS experiment, was reported; and the significance of the results were discussed. It was emphasized that it is impossible to attribute a causal relation to cognitive style on the basis of the evidence available in the correlation coefficient. However, when the results are viewed in light of the many possible sources of variance in the participants' submittal of data items a strong indication portending the eventual identification of cognitive style as a definite influence in data base design is obtained. It was also pointed out that the statistical tests of Hypotheses 2 and 3 will be presented in the next chapter. Fortunately, it will be possible to draw formal inferences, concerning the influence of cognitive style in the Delphi methodology for data base design, from these tests.

CHAPTER 7. COMPARISON OF DELPHI DESIGNS

Five primary Delphi groups were formed to participate in the PFDS project as was discussed in Chapter 4. The basis for subdividing the participants into the five groups was the expectation that they would each converge to data base designs different from one another. This chapter explores the nature of these expected differences. A statistical method is developed for testing if significant differences do exist between data base designs that have been produced through a Delphi type methodology. Then, the results obtained from the application of this statistical method to the designs achieved by the five primary PFDS groups are presented. These results are discussed in terms of both the cognitive style and attitude influences that were apparent in the PFDS effort.

Expected Differences

The five primary PFDS groups--Global, Mixed, Analytical, Attitude, and Control--were each expected to converge to data base designs different from one another. A major influence in this expectation was the homogeneous cognitive style characteristics of the Global, Mixed, and Analytical groups. It was felt that, if individuals with different cognitive styles prefer different types of information to support their decision making activities, then a Delphi group composed solely of individuals with a particular cognitive style type would converge to a data base design significantly different from that obtained by a group composed solely of individuals with a different cognitive style type. The expectations regarding the cognitive style influence in the PFDS experiment are embodied in the second hypothesis of the PFDS study which states that: Three distinct sets of Delphi groups; the first composed of more analytical participants, the second composed of more global participants, and the third composed of participants falling in between the global and analytical extremes; will converge to data base designs that are significantly different.

A second major factor that was expected to influence the type of data base design obtained in the PFDS experiment, concerned the participants' attitudes toward the system. It was theorized that those PFDS participants, who initially held low attitudes toward the system, would be likely to participate in the Delphi data base design process in a manner independent of their cognitive style. For example, it was recognized that the analytical type with a low attitude might refrain from developing detail, to the degree that he was capable, in the data items he submitted and evaluated. These considerations, concerning the influence of attitudes in the Delphi process, are embodied in the third hypothesis of the PFDS study which states that: A set of Delphi grups composed of participants with least favorable attitude scores will converge to a design that is significantly different from the design obtained by groups with similar cognitive style scores but higher attitude scores. In other words, an unfavorable attitude score moderates the cognitive style effect.

Although not formally stated in the form of hypotheses, there was the additional expectation that at least some, if not all, of the four primary groups covered by the cognitive style and attitude factors would converge to data base designs that were significantly different from that of a control group composed of randomly selected participants. It was felt that the Global and Mixed groups would have a high probability of converging to data base designs different from that of the Control group; however, the design of the Analytical group was not necessarily expected to be significantly different from that of the Control group. This speculation was based on the postulated tendency of the analytical individuals to be more profuse and more detailed in the number of data items they would be likely to submit and evaluate. It was felt that the global individuals in the Control group might be overwhelmed by the analytical individuals' more detailed output. Therefore, it was anticipated that the contributions of the global people in the Control group might be minimized, resulting in no significant difference between the data base designs of the Analytical and Control groups.

Statistical Method

Since the PFDS study apparently involved the first attempt to statistically compare data base designs, it was necessary to develop a statistical procedure in order to test the hypotheses concerning the influence of cognitive style and attitude in a Delphi type data base design process. Even though the cognitive style influence was definitely expected to produce a significant difference in the length of the different designs, the mere comparison of the number of data elements in these designs was not aesthetically appealing. One of the major speculations, in the development of the experiment, was that a content difference would also be visible between the different designs. Therefore, it was felt that any statistical procedure used in the comparison should simultaneously take into consideration both the length and content aspects of the designs being tested.[1]

The statistical procedure that was developed basically allows for either a pair-wise comparison between two of the five primary groups or a one-way analysis of variance between three or more of the primary groups. The pair-wise test was adopted for the PFDS experiment, and it is described herein. However, the analysis of variance procedure is very similar.

As was discussed in Chapter 4, the five primary groups, representing the different treatments occurring in the experiment, were each composed of four separate Delphi groups. Each one of these 20 Delphi groups converged separately on importance ratings for a particular set of data items from the master list. The idea behind the statistical test was to determine if the four replications of this process which occurred in one of the five primary treatments were significantly different from the four replications occurring in one of the four remaining treatments. To accomplish this task a t ratio was calculated for the importance rating of each data item that was rated non-zero by one or more of the eight groups involved in a particular pair-wise comparison. In calculating the test statistic for the ith data item (t_i), the importance rating of the ith item (A_i) was considered to be zero for those groups that did not have the ith data item in

[1]The following method, which was used to accomplish this objective, was first proposed by Hugh J. Williamson of the Center for Highway Research at the University of Texas at Austin. His assistance in this critical facet of the experiment is gratefully acknowledged.

their final lists. Thus, the mean importance rating on the ith data item for the kth treatment ($\bar{A}_{ki}$) could be calculated:

$$\bar{A}_{ki} = \sum_{j=1}^{n} \frac{A_{ki}^{j}}{n}$$

where: n=4, the four replications in each PFDS treatment.

k=1 or 2, designating which of the two treatments in the pair-wise comparison is under consideration.

and then

$$t_i = \frac{\bar{A}_{1i} - \bar{A}_{2i}}{\hat{S}_{\bar{D}}}$$

where: $\hat{S}_{\bar{D}} = \sqrt{\frac{n_1 S_1^2 + n_2 S_2^2}{n_1+n_2-2}} \sqrt{\frac{n_1+n_2}{n_1 n_2}}$

$S_k^2 = \frac{\sum_{j=1}^{n} (A_{ki}^{j} - \bar{A}_{ki})^2}{n_k}$, the sample variance.

$n_k = n_1 = n_2 = 4$, the four replications in each PFDS treatment.

The t_i ratio provided an indication of the differences between treatments on the ith data item. The remaining question was to determine if the total of the differences on all items, rated non-zero by one or more of the eight groups, was significant. Since the t_i ratio could be either negative or positive depending on which treatment happened to rate the ith item more importantly, it was necessary to provide a means whereby a summation process to obtain a master test statistic would not result in the cancellation of the differences existing between treatments. Squaring the t_i ratio eliminated this contingency; and it was then possible to sum the t_i^2 for all of those data items considered by at least one of the eight groups, to obtain a master test statistic, which will be denoted as S.

$$S = \sum_{i=1}^{N} t_i^2$$

where: N = total number of items considered by one or more groups.

Since N was large in each of the comparisons, the summation of the t_i^2 was considered to be approximately normal by the central limit theorem. In addition t^2 equals F; therefore, assuming the t_i to be uncorrelated, the expected value and variance of the distribution that was obtained from summing the large number (N) of t_i^2 could be expressed as $N\{E[F(\nu_1, \nu_2)]\}$ and $N\{V[F(\nu_1, \nu_2)]\}$ respectively. Furthermore, the expected value of F is known to be

$$E[F(\nu_1,\nu_2)] = \frac{\nu_2}{\nu_2 - 2}$$

and the variance of F is given by

$$V[F(\nu_1,\nu_2)] = \frac{2\nu_2^2\ (\nu_1 + \nu_2 - 2)}{\nu_1(\nu_2-2)^2\ (\nu_2-4)}$$

Thus, it was possible to test

$$Z = \frac{S - N\{E[F(\nu_1,\nu_2)]\}}{N\{V[F(\nu_1,\nu_2)]\}}$$

against the standard normal distribution to determine if the two data base designs in a particular pair-wise comparison were significantly different in terms of both the length as measured by the number of data items and the content as reflected in the importance ratings.

The primary assumption underlying the development of the statistical procedure is the requirement that one or more of the eight groups must consider a particular data item in order for it to be included in the analysis. Since it is theoretically possible to construct an almost infinite number of data items, the requirement, that at least one of the groups consider each data item, is necessary in order to be able to detect any difference whatsoever in the data base designs. If data items were included which were not considered in any of the group lists, then the eight group importance ratings would all be zero; and there would be no differences existing in regard to those particular items. If a large number of these items were included in the analysis, no differences would be apparent between any of the data base designs. It is, therefore, obvious that the requirement of a data item having to be considered by at least one group is justified; however, the question remains of whether or not two, three, or even four groups should be required to have considered an item before it is included in the analysis.

In the statistical procedure that was followed in the PFDS experiment, the question, of how many groups need to consider a particular data item before the item warrants inclusion in the summation process, was approached by conducting a sensitivity analysis in which the number of groups required to intersect an item was varied. The sensitivity analysis not only provided a method for coming to grips with the number of groups required to intersect an item problem, but it also provided a check on the efficacy of the statistical procedure. By observing the changes in the significance levels as the number of groups was varied, it was possible to conclude that the procedure was converging and functioning as intended. These considerations are discussed at greater length in the next section when the results from comparing the PFDS data base designs are presented.

PFDS Experimental Results

The statistical procedure outlined above was applied to the data base designs achieved by the five primary PFDS groups. Each possible pairwise comparison in the set of five primary groups was performed; and the results of the ten comparisons are presented in Tables 1, 2, and 3. Tables 1, 2, and 3 were compiled under the three separate and respective restrictions that at least one, two, and three of the eight Delphi groups involved in a comparison had to have considered a particular data item in order for the item to have been included in the summation process to obtain the master statistic. The first two columns in the three tables indicate which two primary groups were involved in each of the ten comparisons. The third column gives the number of data items that were included in the summation process. The fourth column presents the Z score for each of the comparisons, and the fifth column indicates the levels at which any differences are significant. Due to the nature of the statistical procedure, the negative Z scores are not meaningful, and only the positive Z scores were used to obtain the significance levels.

A brief review of the three tables provides information not only on the sensitivity of the statistical procedure, in terms of the number of

TABLE 1. COMPARISON OF DELPHI DESIGNS
AT LEAST 1 GROUP PER ITEM

Group vs.	Group	Number of Data Items	Z Score	α
Global	Mixed	502	5.184	.000005
Global	Analytical	617	1.907	.05
Global	Attitude	500	-2.432	-
Global	Control	813	15.185	.000005
Mixed	Analytical	666	-1.171	-
Mixed	Attitude	565	-2.547	-
Mixed	Control	852	10.135	.000005
Analytical	Attitude	676	.171	-
Analytical	Control	938	-2.279	-
Attitude	Control	868	-1.733	-

TABLE 2. COMPARISON OF DELPHI DESIGNS
AT LEAST 2 GROUPS PER ITEM

Group vs.	Group	Number of Data Items	Z Score	α
Global	Mixed	208	11.093	.000005
Global	Analytical	272	5.991	.000005
Global	Attitude	206	-.736	-
Global	Control	289	30.064	.000005
Mixed	Analytical	300	1.405	.1
Mixed	Attitude	242	-.797	-
Mixed	Control	346	19.960	.000005
Analytical	Attitude	308	3.379	.0005
Analytical	Control	389	.611	-
Attitude	Control	326	1.647	.05

TABLE 3. COMPARISON OF DELPHI DESIGNS
AT LEAST 3 GROUPS PER ITEM

Group	vs.	Group	Number of Data Items	Z Score	α
Global		Mixed	112	15.702	.000005
Global		Analytical	144	7.154	.000005
Global		Attitude	113	-.807	-
Global		Control	159	39.790	.000005
Mixed		Analytical	182	2.098	.025
Mixed		Attitude	146	-.276	-
Mixed		Control	186	27.457	.000005
Analytical		Attitude	168	4.142	.00005
Analytical		Control	227	1.150	-
Attitude		Control	179	1.997	.025

groups required to intersect each item; but it also yields an indication of how well the method meets the objectives of simultaneously considering both length and content. As the number of groups required to intersect an item is increased from one in Table 1 to three in Table 3, the joint number of items considered by the eight Delphi groups involved in each comparison decreases. The number of data items considered also increases as a function of cognitive style in each of the three tables. As expected, the Analytical-Control comparison is based on a larger number of joint items (938) than the Global-Mixed comparison (502). The role that content plays in the statistical procedure is indicated by the fact that the number of joint items is approximately the same for the Global-Mixed (502) and Global-Attitude (500) comparisons; however, the Global-Mixed comparison indicates a significant difference in designs at a high confidence level, while the Global-Attitude comparison indicates no significant difference in designs. Finally, the Z scores and significance levels appear to be moving toward convergence as the required number of groups is increased from one to three. These factors all tend to indicate that the statistical procedure functions as intended.

Unfortunately, it is impossible to conclude from the sensitivity analysis exactly what the optimum number of required groups should be; nevertheless, the sensitivity study does provide a framework for the discussion of the results. The sensitivity information is used, in the next two sections, to discuss the changes that occur in the comparisons as the number of groups required is altered.

Cognitive Style Comparisons

The null form of Hypothesis 2 states that there are no significant differences in the data base designs achieved by the Global, Mixed, and Analytical cognitive style groups. Tables 1 through 3, which present the results of the statistical tests, provide an indication as to whether or not the null hypothesis should be rejected in favor of Hypothesis 2. There are three pair-wise comparisons--Global-Mixed, Global-Analytical, and Mixed-Analytical--in the tables, that are relevant to the problem of determining what influence cognitive style might have had in the data base designs. A review of the three comparisons across the three tables can be used to address the question of what degree of confidence can be placed in the rejection of the null hypothesis.

The Global-Mixed comparison shows that a significant difference, at a very high confidence level, exists between the data base designs of the two groups in all three tables. Although in Table 1 the Global-Analytical comparison is significantly different only at the $\alpha = .05$ level, the confidence in this difference becomes much greater when either two or three groups are required to have considered an item as indicated in Tables 2 and 3. However, the Mixed-Analytical comparison does not show a significant difference until Table 3 and then only at a moderate level of confidence. The results could possibly be viewed as somewhat mixed, since all three comparisons were not significantly different in all three tests. Nevertheless, there still appears to be ample evidence for rejecting the null hypothesis with a high level of confidence.

Even in light of the small sample size, the results are especially encouraging for the cognitive style theory. The significant difference in the Global-Mixed comparison at the $\alpha = .000005$ level in all three tables lends a high degree of confidence to the rejection of the null hypothesis. The failure to disconfirm Hypothesis 2 in the PFDS experiment and the lack of immediately apparent plausible rival hypotheses to account for the difference offer a great deal of support to the theory that cognitive style is likely to be an influence in information system design.

Attitude Comparisons

The null form of Hypothesis 3 states that there will be no significant difference between the data base designs achieved by Delphi groups composed of participants with least favorable attitude scores and the designs achieved by groups with similar cognitive style scores but higher attitude scores. Table 4 presents the mean Hidden Figures Test (HFT) scores for the various groups participating in the PFDS study. The information in Table 4 can be used in conjunction with Tables 1 through 3 to evaluate the possibility of attitude acting as a moderating variable on the cognitive style effect.

TABLE 4. GROUP HFT SCORES

Group	Mean HFT
All Participants	10.25
First Control	11.56
Entire Delphi	10.08
Global	4.12
Mixed	10.62
Analytical	17.29
Attitude	7.64
Second Control	10.20

From Table 4 it can be seen that the mean HFT score for the Attitude group is 7.64 and that this score falls approximately in the middle of the mean HFT scores for the Global (4.12) and Mixed (10.62) groups. Referring to Tables 1 through 3, both the Global-Attitude and Mixed-Attitude comparisons show no significant differences in any of the three tables; but both the Analytical-Attitude and Attitude-Control comparisons do begin to show significant differences as the number of groups required is increased. However, it should be noted that the Attitude-Control difference is not as significant as the Analytical-Attitude difference. In conjunction with this observation, it should also be noted, that in Table 4 the Second Control group mean HFT score is approximately equal to the mean HFT score of the Mixed group.

From these facts it is impossible to derive any evidence whatsoever that would support the rejection of the null hypothesis regarding the performance of the Attitude group. Therefore, it is concluded that attitude does not act as a moderating variable on the cognitive style effect.

Unobtrusive Measures

In an attempt to cross-validate the cognitive style and attitude effects, four supplementary measures, in addition to the cognitive style and attitude scores, were maintained on each participant. The results from the first of these measures--the time the individual participants took to return their Delphi communications for each iteration--are presented in this chapter. The other three supplementary measures are discussed in Chapter 8.

"Once a proposition has been confirmed by two or more independent measurement processes, the uncertainty of its interpretation is greatly reduced." Furthermore, the validity of the interpretation is even more enhanced if one or more of the multiple measures is unobtrusive in nature, i.e. it does not require the cooperation of the subject and the measurement process itself does not contaminate the response (Ref 87, pp 2-3). The time to return measure meets the above criteria, since the PFDS participants were completely unaware that their responses were being evaluated in this regard.

The number of days that each participant took to return the Delphi communication was recorded for each iteration. The time to return for the initial submission phase was measured from the day of the presentation to the day the initial input forms were received by the administrator, and the time to return for the subsequent iterations was measured from the day the Delphi communication was mailed until the day it was returned to the administrator. Since the participants worked individually during the initial submission phase and as a group during the subsequent iterations, separate averages for the time to return were developed for the initial submission and group phases of the Delphi process. Thus, a mean time to return for each of the 20 Delphi groups was calculated for both the initial submission and group phases of the process. This resulted in four replications of the average time to return for each of the five treatments in the experiment.

Next, a *t* test was performed on the mean time to return for each possible pair-wise comparison in the set of five primary groups. The ten pair-wise comparisons were evaluated for both the initial submission and group phases of the process. No significant differences were found in any of the comparisons for the initial submission phase, and the results of the ten comparisons for the group phase are presented in Table 5. The negative sign in the *t* score indicates that the group on the right in the Group vs. Group column took longer to return the Delphi communications than the group on the left.

The fact that the tests of the time to return in the initial submission phase did not show any significant differences indicates that the differences in the subsequent iterations are a result of a combination of both cognitive style and participation in the Delphi process. It is also interesting to note that the length of the Delphi communication apparently has little, if any, effect on the time to return statistic. This fact is pointed out by both the lack of significant differences in the initial submission phase as well as the lack of a significant difference in the Global-Analytical comparison in the subsequent iterations phase. The converged Analytical designs were much longer than the converged Global designs; and, if length were a factor in the time to return, it would be apparent in the Global-Analytical comparison.

The Control group was composed of randomly selected individuals; therefore, it contained a wide range of cognitive styles. Reference to Table 5 shows that the more homogeneous Global, Mixed, and Analytical

TABLE 5. TIME TO RETURN SUBSEQUENT ITERATIONS

Group	vs.	Group	t	α
Global		Mixed	-1.3331	.5
Global		Analytical	-.2486	-
Global		Attitude	-1.9474	.05
Global		Control	-4.5196	.0025
Mixed		Analytical	.4507	.8
Mixed		Attitude	-1.0952	.25
Mixed		Control	-3.6685	.01
Analytical		Attitude	-1.0841	.25
Analytical		Control	-1.9910	.05
Attitude		Control	-1.0232	.5

groups all required significantly less time to return than the Control group. These differences are statistically significant at the .0025, .01, and .05 levels respectively. The Attitude group was also composed of participants with divergent cognitive style scores; however, the mean of the scores is much less than for the Control group. Therefore, it is not surprising to find that similar differences, which are by no means as significant, also exist in the Global, Mixed, and Analytical vs. Attitude comparisons. This probably indicates that the homogeneous cognitive style grouping is more supportive or at least less frustrating to the Delphi participants than a grouping that requires the participants to deal with group members who have significantly different cognitive styles.

The differences, between the cognitive style groups in regard to the time to return, confirm the presence of the cognitive style effect that was found in the data base designs. This cross-validation with an unobtrusive measure lends a great deal of weight to the theory that cognitive style is a factor that must be recognized and dealt with in information system design.

Summary

The differences that were expected to be observed between the data base designs achieved by the five primary PFDS groups were discussed in terms of: (1) Hypothesis 2, which covers the cognitive style effect; and (2) Hypothesis 3, which covers the effect of attitude on cognitive style. A statistical procedure, which was developed to test these hypotheses, was then discussed. The prime objective in the development of the statistical procedure was to obtain the ability to compare the data base designs in terms of both length and content. The results, from the application of the statistical procedure to the data base designs achieved by the five primary PFDS groups, were presented in the form of a sensitivity analysis that incorporated three variations of a primary assumption underlying the procedure. The results of comparing the data base designs achieved by the cognitive style groups were discussed, and it was concluded that the results lend a great deal of support to the theory that cognitive style is a factor that must be dealt with in information system design. The results of comparing the data base designs achieved by the

Attitude group with those achieved by other groups were also discussed; and it was concluded that a low attitude does not act, to any appreciable degree, as a moderator of the cognitive style effect in the Delphi data base design process. The results from an unobtrusive measure, that confirmed the presence of a cognitive style effect in the PFDS experiment were discussed; and it was concluded that this independent verification lends a great deal of weight to the theory that cognitive style is a factor which should be considered in information system design.

CHAPTER 8. DELPHI: A SUBJECTIVE APPRAISAL

Quite often in experimental research, soft data is available in the form of investigator impressions; and although these impressions are by necessity contaminated at least to some degree with investigator bias they may still be worthy of mention. In this regard, this chapter examines some of the opinions, impressions, and observations of the Delphi administrator that were recorded during the PFDS project. Consequently, it must be cautioned at the onset of the chapter that the data which is discussed, albeit interesting, has the possibility of being highly contaminated by the investigator's personal bias. In addition, the data is not readily quantifiable and amenable to stringent statistical tests; therefore, any inferences that are drawn must be of a highly speculative nature. With these caveats firmly in mind, the chapter will begin with a brief review of where the Delphi methodology is perceived to fit in the design process. Then some of the possible alternatives that are available for subsequently utilizing the results of the Delphi method in the technical stage of the design process are presented. The application of Delphi in the PFDS data base design project is used as an example to illustrate these concepts. Next a general discussion of the trade-off between the costs and benefits of applying the Delphi methodology in the area of data base design is conducted. Finally, several observations of the administrator regarding differences between cognitive style groups are reported.

Delphi in Perspective

In Chapter 1 it was pointed out that the data base design process can be roughly divided into two categories. The first treats the problem of identifying the user's information needs and specifying how the data is to be collected, while the second deals with the problem of classifying the data items and establishing the data structure. In addition it was also pointed out that the first step in the design process can be considered to be of a non-technical nature from the user's viewpoint, while the second step requires a technical competency that the users of a system may not normally possess. The Delphi methodology that is proposed in this report has been shown to be an effective method for handling the problems associated with the non-technical side of the design process. However, difficulty was encountered when an attempt was made to extend Delphi into the technical area during the PFDS project. Therefore, this section of the chapter briefly presents the PFDS data base design project administrator's views as to how the results of a Delphi process might be utilized during the technical stage of the total design task. The purpose is to illustrate the relative position of the Delphi methodology in the overall design effort. The PFDS project will be used, in both this section and the next, as an example to illustrate this relationship.

As a general rule, this investigator would only recommend the use of multiple Delphi groups in those situations where it is desirable to examine the effects of experimental variables on the resulting data base designs. As a consequence of this policy, a single data base design would normally result; and after all redundancies have been eliminated those data items, that were ranked above some established level in regard to importance, would be included in the final list of data items. For those cases where multiple Delphi groups are used, the procedure that was utilized in the PFDS project is recommended until further research can produce better methods for combining the results from multiple groups.

The combining process used in the PFDS project is described in detail in Chapter 3, and it is briefly reviewed here. A pass down the master list of data items is made, and the mean and range of the importance ratings calculated from the importance ratings of all groups considering each item are output. If an item has a high mean and a small range, it is definitely included in the final data item list. Likewise, if an item has a small mean and a small range, then the item is definitely excluded from the final list. Those items that are not clearly defined by this criteria are reserved for further consideration.

In the case of multiple groups where the automatic procedure for eliminating redundancy is to be utilized, it is preferable to apply the elimination procedure after the combining process has been performed. This precaution avoids the possibility of retaining different items of the same redundancy in different groups and having the redundancy reappear in the combined final list. Consider as an example the converged lists of data items, included in Appendix C, that were derived by two of the PFDS Delphi groups. The first list, individual number 40, is from a global group; and the second list, individual number 120, is from an analytical group. Data items 420 through 424 all deal with the thickness of the base; and they can be considered a redundancy, although it is recognized that there may be separate data items for the thickness of the base for the traffic lane and the thickness of the base for the shoulder. The list from the analytical group has clearly rated items 421 and 422, Base Thickness-Traffic Lane and Base Thickness-Shoulder, as being more important than items 420 and 424, Base Thickness and Flex Base-Depth. In contrast, the global group has rated item 424 more important than item 420 for expressing the base thickness of the traffic lane. If the redundancy were eliminated in the separate lists before they were combined, it is not clear that the redundancy would not reappear in the final list. Therefore, it is preferable to apply the elimination procedure after the combining process has been performed. This same set of data items also provides an example of the qualitative differences that were observed between the results of the different cognitive style groups, and the example will be referred to in a subsequent section of this chapter when these differences are discussed.

Thus, in the event of either single or multiple groups the objective of the Delphi process which is described in this report is to provide a final, non-redundant list of data items which have been recommended by the potential users for inclusion in the data base. Coupled with the information on who is to supply the data items, the final data item list symbolizes the accomplishment of Step 1, the non-technical stage of the data base design process. This list is then used during Step 2, the technical stage of the data base design process, to finalize the data base design.

First, the data item descriptors which have been ranked high enough in importance during the Delphi process to warrant being retained in the data base must be transformed into more definitive data elements. The data element definition precisely specifys the nature of the data included in the particular data element; and it contains such items as dimensional information and whether the element is composed of alphabetic or numeric characters. The process of compiling this portion of the data element dictionary could conceivably be handled by a systems analyst working in conjunction with specialists in the particular fields encompassed by the data, by a committee, or by additional Delphi groups. This investigator feels that the Delphi process possibly holds some potential for assisting in the preliminary stages of developing the data element definitions. For example, in the PFDS design project small Delphi groups composed of specialists in a particular function could develop the precise specifications for the data elements related to their functional area, i.e. flexible pavement experts could consider the asphalt related data items and rigid pavement experts could consider the concrete related items. The concept at least appears to warrant further consideration, and it is an area in which further research is recommended.

The next step in the design process involves the determination of the logical structure or hierarchical ordering of the data elements. However, at this stage in the development of the Delphi process it is not clear that the potential users are capable of assisting in the design of the logical structure for a data base. Furthermore, it is not obvious that their participation would add anything of value to the quality of the data base. Further research to clarify the advisability of having the potential users participate in this area is, therefore, called for. On the other hand, this investigator feels that the participation of the potential users in the final step of the design process, development of the physical structure of the data base, is definitely not warranted and would probably lead to disastrous consequences.

In summary, it is this investigator's opinion that the evidence found in the PFDS experiment warrants the conclusion that the Delphi method possesses excellent potential for widespread application in the nontechnical phase of the data base design process. However, the advisability of extending the method into the technical stage of the design process is still open to speculation; and the question needs to be resolved through further research. In addition, the successful involvement of a large number of the potential users of PFDS illustrates that the Delphi process may be a method for effectively implementing the participation in organizational decision making that is so widely touted in the management literature and has up until now been just as widely ignored in terms of methods for implementation. As such, it is this investigator's opinion that the Delphi process, which is examined in this report, can be more widely viewed as a potential means for implementing the participative management philosophy. In this vein, the statistical results from examining the participative effect of the Delphi process in the PFDS project are reported in the next chapter.

Delphi in PFDS

In the PFDS project, the Delphi procedure was conducted by a research group, from the Center for Highway Research, working on behalf of the potential users of the system. Participants in the project were composed of 241 potential users from several of the Headquarters Divisions and all of the District offices in the Texas Highway Department (THD). Furthermore, the participants consisted of individuals from several functional areas in the Department such as design, maintenance, and research.

The computer systems specialists, who have ultimate responsibility for the implementation of all computer systems in the THD, participated in Step 1, the non-technical phase of the project, only as observers. After the PFDS Delphi had been run to convergence in three iterations, the computer systems personnel then requested that the results from combining the output of the 21 groups, which was discussed in Chapter 3 and also in the immediately preceding section of this chapter, be supplied to them in order that they might begin Step 2, the technical phase of the data base design process. Thus, the PFDS Delphi project yielded a list of 1310 data items which were rank ordered in regard to their importance as perceived by 241 potential users of the system.

It is important to realize that the PFDS data item list does not constitute a data base, but only a set of descriptors for data items that the potential users feel are important enough to be included in the system. As such the output of the Delphi process can be viewed as only a rough overall design of the framework for the data base. The detailed technical design of PFDS must still be completed, and this detailed design effort will by necessity have to be undertaken with regard for the data base management system and other technical considerations that influence the physical structure of the data base.

Cost vs. Benefit

Ordinarily one of the more central concerns in the adoption of a proposed policy is the determination, with at least some degree of certainty, that the policy will be cost effective. Unfortunately, the Delphi process, because of the lack of specific benefit figures resulting from the method's rudimentary stage of development, can not as yet be rigorously shown to be cost effective. However, a brief review of some of the more salient cost and benefit considerations may assist a potential applier of the Delphi process in arriving at his own intuitive appraisal of the method's worth.

On the cost side of the ledger, the application of a Delphi methodology to the problem of data base design requires major resources from the following areas:

(1) potential users' time,
(2) administrator's time,
(3) data entry, and
(4) computer time.

Ignoring for the moment the benefits accruing from the achievement of a more representative and possibly more useful data base and the benefits arising from the participative effect which is likely to promote increased and more intelligent use of the system, we are left with the question of what is the likely difference in cost between the Delphi and traditional methods of implementing a data base. It is this investigator's opinion that there is little or no difference in cost either way between the two methods. The Delphi method merely requires the reapportionment of the resources normally expended in the implementation of a data base system which happen to be approximately the same as the resources listed above.

The basis for this opinion derives from the belief that the resources expended in the Delphi effort can be recovered during the training phase associated with data base implementation. Normally the users of a data base system must spend a great deal of time becoming familiar with and gaining an understanding of the data definition underlying a data base. It is felt that the involvement of the potential users in a Delphi type design effort will greatly diminish the additional time required for them to achieve the familiarity and understanding necessary for effective utilization of their system. In fact it is this investigator's impression that the Delphi process can be completed in less time than an equivalent training program. Similarly the administrator's time is believed to be about the same as that required by an instructor to assist the users in achieving an equivalent degree of understanding during the training phase. In addition, it is believed that the resources expended on data entry and computer time during the Delphi process can be recovered from the user's more efficient use of the computer during the learning process. As a result of these trade-offs it is believed that the total expenditures required to bring a data base system to the operational stage either through a Delphi type methodology or a more traditional approach are approximately the same.

Even if the potential applier of the Delphi method is unconvinced of the cost equivalency of the two approaches, he must still consider the more representative nature of the Delphi derived data base. A better representation of the users' data needs is bound to lead to more effective utilization of the system. Furthermore, the participative effect accruing from the application of a Delphi type methodology is likely to be the deciding factor in whether or not the system is used enough to warrant its existence. These additional considerations surely offset any cost difference that may exist between the two approaches.

Administrator Observations

A couple of interesting relationships can be observed in the data which were developed in the preceding chapter. First, the Attitude group not only has a low attitude but it also has a substantially lower mean HFT score than the Second Control group which was randomly selected. This might possibly tend to indicate that the global individual is on the average more likely to have a lower attitude toward a data base system than the analytical type. This could be a result of the global individual's propensity to ignore, in his decision making activities, the types of information normally present in data base systems. Second, the Analytical-Control comparison was the only comparison involving a cognitive style group and the control group that failed to show a significant difference in Tables 1, 2, and 3. This result might be explained by the global individual's tendency to be overcome by the more profuse output of the analytical type. Therefore, there may be no reason to expect a difference to exist between the data base designs achieved by Analytical and randomly selected groups.

Furthermore, the administrator of the Delphi process observed several phenomenon, during the course of the PFDS experiment, which also confirm the presence of the cognitive style effect. Although the observations are not supported by stringent statistical tests and merely represent investigator opinion; they are nevertheless considered to be worthy of mention.

It was observed that the data items developed by the Global group tended to be more general or global in nature than the data items developed by the analytical groups. The global types seemed to be more concerned with specifying types of information that they would like to have in reports rather than specific elementary data items. For example, the data items specified by the Global groups were often capable of being calculated from more elementary data items. In contrast, the analytical types appeared to be more interested in breaking the data items down into their most elementary form. In this regard the analytical types were much more specific with their descriptors than the global types, and a couple of the analytical participants in the Control group evidenced some concern that the descriptors were not being specified in enough detail. On the other hand the global types appeared to be much more comfortable with any ambiguity that existed in the descriptors.

An example of these differences can be found in the data items that were used in the first section of this chapter to illustrate the method for eliminating redundancy. In specifying the data items for base thickness (items 420 through 424) the analytical group was clearly more specific and detailed in their selection than the global group. The reader is reminded that the converged data item lists from both a global group (individual number 40) and an analytical group (individual number

120) can be found in Appendix C. In these lists it can be observed that the analytical group rated both Base Thickness-Traffic Lane and Base Thickness-Shoulder as 5.0 while rating the other descriptors for base thickness much lower. In contrast, the global group was much less specific in identifying the data item descriptor or descriptors they preferred for base thickness.

Although it was difficult to generalize from the few observations that were available, it appeared that the global types were probably more free and creative in their expression of data items while the analytical types appeared to be bound to more conventional types of data. For example, some of the global types expressed data items that had apparently never been used or previously considered, while the analytical types showed a tendency to rely on standard engineering practice, e.g. sometimes including items directly from highway specifications.

Examples of these phenomena can be found in the two converged data item lists that are included in Appendix C. Items 782 through 787 which deal with sources and uses of funds can be found in the global group's list while the items are completely ignored in the analytical group's list. Only one reference to a specification item can be found in the global group's list while seven references to specification items are apparent in the analytical group's list.

The Delphi administrator's observations of the participants' performances during the project also offer a contribution toward understanding the attitude change that took place. As the participants progressed through the Delphi process, their enthusiasm for the project appeared to increase rather than wane as might be expected. Toward the latter part of the project, the participants' conversations with the administrator began to take on a much more friendly and constructive tone. For example, participants, with whom the administrator might be conversing, frequently offered to prompt other participants in their District who were late returning the printouts. Although a degree of relaxation and increased friendliness would normally be expected, the significant increase in the intensity of the participants' interest that was observed is interpreted as indicating a much greater improvement in attitude than was measured by the questionnaire. It is theorized that this attitude improvement was toward the organization and those implementing the system rather than directly toward the system itself as measured by the attitude scale. The results of the statistical tests which were performed to verify the existence of the participative effect in the PFDS project are discussed in the next chapter. The observations of the administrator were reported here in order that the reader might gain a better appreciation of the attitude change that took place during the PFDS project.

Summary

This chapter was used as a vehicle to report the Delphi administrator's observations and impressions of the functioning of the Delphi method in the PFDS project. The first section of the chapter examined the relationship of Delphi to the overall data base design process while the second section illustrated the relationship with a discussion of the application of Delphi in the PFDS data base design project. The third section presented some general considerations on the cost effectiveness of the method; and finally in the fourth section, several observations of the Delphi administrator, which support the cognitive style conclusions, were reported.

CHAPTER 9. EFFECT OF USER PARTICIPATION IN THE DESIGN PROCESS

A Delphi type methodology for data base design is predicated on the assumption that the potential users of an information system will actively participate in the data base design process. Therefore, the question, of what effect this participation is likely to have on the participants' attitudes toward the system, is of central interest. The first section of this chapter examines the expectations, regarding the influence of participation on the attitudes of the potential users, that are embodied in the fourth hypothesis of the PFDS study. The next section sets out the statistical procedure that was followed in testing this hypothesis and presents the results that were obtained in the PFDS experiment. Finally, these results are discussed in terms of their importance for the future application of the Delphi methodology in the area of data base design.

Expectations Regarding Participation

The effects that take place as a result of encouraging an organization's members to actively participate in the organization's decision making activities have received a great deal of attention over the last two decades. It is believed that this style of leadership, which has been labeled the *participative management approach*, leads to increased excellence in decisions as well as other benefits which stem from an increase in the morale of the organization's members.

The Delphi approach to the problem of data base design falls in this category. It provides an excellent means for tapping the expertise of the most knowledgeable people, to determine what the contents of the data base should be; and theoretically the approach also offers many advantages arising directly from the participative process it engenders. In fact the two classes of benefits appear to be inextricably linked, since in the past the greatest successes arising from the participative approach have been in areas where the participants have had something worthwhile to contribute, as do the potential users of a data base system.

The participative approach is particularly well suited to situations in which the solution alternatives are approximately of equal quality, and the participants are qualified because of their education and/or experience to render an opinion related to the problem. The greatest benefits from the approach are realized when a high quality decision is required in an ambiguous situation, and the successful implementation of the decision depends on group acceptance. There are various benefits which have been identified as being related to the participative approach. For example, in circumstances where the above conditions have been met, the approach has been found to lessen resistance to change, to promote stronger organizational identification, and to elicit greater effort toward obtaining organizational goals.

The data base design process appears to be an excellent opportunity for use of a participative approach. In a data base there are many sets of data elements that would be of approximately equal value, and group acceptance of an information system is critical to its effectiveness. The Delphi approach to data base design, by its very nature, requires the participation of the potential users of the system; therefore, some of the advantages of the participative approach are expected to occur from the use of the technique.

A critical measure of the success of an information system is the degree to which the system is used; and it is expected that the usage of a system will be improved as a result of applying the Delphi approach to the design of the data base. In the PFDS study it was impossible to obtain usage measures for a system that was non-operational and still in the planning stages; therefore, a surrogate measure for usage was adopted. Attitudes toward an object reflect a predisposition to respond to the object in a favorable or unfavorable way. In fact the Schultz-Slevin attitude scale that was adopted in the PFDS study has been found to be significantly correlated with an expressed intention to use an MIS innovation when it became operational. Thus, Hypothesis 4 was formulated, which states that the attitude scores of all PFDS groups will be improved as a result of participating in the Delphi process.

Statistical Method and PFDS Results

The null form of Hypothesis 4 states that the mean attitude score of at least one of the five primary PFDS groups will have failed to improve as a result of participating in the Delphi project. In order to test this hypothesis the attitude scale was first administered during the District presentations as was discussed in Chapter 4. Then after all Delphi groups had converged, the attitude scale was readministered by mail to all participants. The individual results from the first and second attitude scale administrations are included in Appendix E under the titles ATT (PRE) and ATT (POST) respectively. The means of both scores were computed for each of the five primary PFDS groups, the First Control group, and all groups that participated in the Delphi project combined. The 27 subjects in the First Control group only completed the tests and did not participate in the Delphi project. The purpose of the First Control group was to provide assurance that extraneous variables were not involved in any improvement that might be noted in the other groups. The mean scores for the groups were calculated as matched pairs without the scores from the subjects who dropped being included in the calculation.

A t test for dependent samples was performed, on the difference between the matched attitude scores, for each of the seven groups mentioned above. Although the specific hypothesis was stated in the form of an improvement in the attitude scores, there was a broader interest in whether or not the attitude scores of the groups changed in either direction. Therefore, the significance level of the attitude difference for each group was determined on the basis of a two-tailed test even though the hypothesis was stated in the form of a one-tail test.

The results of the t tests are presented in Table 6. The first column indicates the group involved. The second and third columns give the mean attitude scores before and after the Delphi treatment; and the fourth column provides the difference in the two scores. A positive score indicates improvement in attitude on the part of the group; and a negative score indicates a deterioration in attitude. Finally, the fifth column presents the level at which the differences were found to be significant.

TABLE 6. ATTITUDE CHANGE

Group	Mean Pre-Att	Mean Post-Att	Att Difference	α
First Control	66.15	62.85	-3.30	.05
Entire Delphi	64.01	65.54	1.53	.05
Global	67.05	68.80	1.75	.1
Mixed	69.32	68.72	-.60	-
Analytical	67.97	66.62	-1.35	-
Attitude	50.92	59.54	8.62	.0005
Second Control	63.86	63.46	-.40	-

Discussion of the Results

The First Control group was included as a precautionary measure to assure that any positive change in the participants' attitudes was definitely a result of their participation in the Delphi process and not due to the intervention of some extraneous variable. An examination of the first entry in Table 6, which presents the data pertinent to the First Control group, gives a positive indication that the control group's ability to perform its function as intended was not impaired. In this regard, it may be noted that the mean of the pre-attitude scores of the First Control group appears to be considerably greater than that of either the Entire Delphi or Second Control groups. Both the first and second control groups were randomly selected from all of the participants; therefore, it would be expected that the means of the pre-attitude scores of the First Control, Entire Delphi, and Second Control groups would be approximately the same. This fact is borne out in the closeness of the means of the pre-attitude scores of the Second Control group and the Entire Delphi group. In order to resolve the possible discrepancy, a t test was performed which compared the mean of the pre-attitude scores of the First Control group against that of the Entire Delphi group. No significant difference was found between the two means at the .05 level; and it was concluded that the apparent difference was due to chance. Therefore, it was assumed that the function of the control group was not impaired by some unaccounted for influence.

Between the two administrations of the attitude scale, the First Control group experienced a downward shift in attitude that was significant at the .05 level. An analysis of the possible reasons behind the downward movement revealed that there are several factors and combinations of factors that could have contributed to this shift. As an example, four of the possible reasons are enumerated below:

(1) a downward shift in the attitude scores of all participants resulting from the intervention of extraneous variables between the two administrations of the attitude scale;

(2) a feeling of rejection on the part of the control subjects for not being allowed to participate in the Delphi project;

(3) the participation effect may have taken place when the subjects were initially invited to attend the presentation, and the rejection of the control subjects returned their attitudes to their normal pre-participation levels; and

(4) a positive shift in attitude was experienced by all participants but the rejection effect discussed in reason (2) caused a total downward shift in the attitude of the control group.

No attempt was made to determine the specific reason behind the shift in the control group. Since the attitude change of the control group was in the opposite direction of the attitude change experienced by the Entire Delphi group, it was assumed that a conservative estimate of the participation effect could be obtained by ignoring the attitude shift of the First Control group. This assumption was predicated on the belief that the probability was very small that reason (4) accounted for the shift in the control group.

Under the probably conservative assumption that the results from the First Control group can be ignored, it is impossible to reject the null hypothesis which predicted that the mean attitude score of at least one of the five primary groups would fail to improve as a result of participating in the Delphi project. Thus, the specific research hypothesis, that all groups will improve as a result of Delphi participation, failed to gain support from the PFDS experiment. However, an overall gain, for the Entire Delphi group, that was significant at the .05 level was experienced. This result tends to indicate that participation in the Delphi process does lead to improvement in the participants' attitudes toward the system, although not to the widespread extent that was initially expected.

In analyzing the group components of the overall attitude improvement, extreme care must be exercised in jumping to the possibly specious conclusion that the great majority of the increase is due to the low attitude group. Statistical regression toward the mean, which invariably occurs when subjects are segregated into groups on the basis of extreme scores, probably accounts for a large proportion of the apparent increase found in the Attitude group. Less substantial evidence of this phenomenon can also be found in the Analytical group where the mean pre-attitude score lies toward the upper end of the attitude continuum. Regression toward the mean may account for the apparent decrease in attitude in the case of the Analytical group. In contrast, the Mixed and Global groups, which also lie toward the upper end of the attitude continuum, do not demonstrate the corresponding decrease in attitude that would be expected. In addition, the positive attitude change of the Global group is significant at the .1 level in the two-tail test and would have been significant at the .05 level in a one-tail test; therefore, it is concluded that the Global group sustained an appreciable increase in attitude as a result of the Delphi process.

In addition to the Hidden Figures Test (HFT) and attitude scale scores, four other observations were maintained on each individual in an attempt to provide multiple measures for cross-validation of the cognitive style and attitude concepts. The first of these measures, the speed of return of the Delphi communications, was previously referred to in Chapter 7. As a second measure, it was noted whether or not an individual's list of initial data items was typed. Then, at the end of the experiment, the participants were given an opportunity to request a copy of their group's printout to keep for their records; and, as a third measure, it was noted which individuals actually made the request. The three measures are less obtrusive than the HFT or attitude scale; but unfortunately no correlation could be detected between the typing and request for copy measures and any aspects of the PFDS experiment.

However, the fourth measure, which is also obtrusive in nature, provided useful information regarding the participants' attitudes toward the Delphi process. An optional free-form space was provided on the second attitude questionnaire where the PFDS participants were allowed to make any comment they desired about the Delphi process in which they participated. Comments were received from 66 of the 201 Delphi participants who completed the questionnaire. Out of the 66 comments there was not a single remark that could be considered derogatory to the use of Delphi as a method for data base design. Several of the participants' comments are listed below:

> I believe the Delphi process to be the best possible way to compile the index for an informational file of this nature (26).

> The Delphi process would appear to be an excellent tool for implementing this type of system (150).
>
> I consider it a great compliment to be considered in the process. Very informative on my part, being able to read each participants' comments and know your comments are of equal value (25).
>
> This was a very interesting experience. The opportunity to have my input evaluated by the Delphi process was very much appreciated (65).
>
> In my opinion, considering the number of people involved in this process, consummation of the project has been completed in minimum time. Compared with old method--over the table argument and constant personal disputes--I would say some twelve to eighteen months would have been required (170).
>
> I think the Delphi process is excellent for this type of data system; however, I would like to reiterate that numerous data items were duplicated or were closely related, and the number of data items should be minimized (163).

The numbers in parentheses following the quotes, are the individual numbers of the people that made the comments. The individual numbers are included in order that the reader may compare the quotes with the corresponding individual data in Appendix E, if he so desires.

Several comments, similar to the last comment quoted above (individual number 163), were received from the participants both verbally throughout the process and in writing as a part of the second attitude questionnaire. These comments have prompted the conclusion that the redundancy is probably best eliminated by an expert in the particular field, during each round, instead of relying on the Delphi process to perform this function as was described in Chapter 3.

Another interesting insight was also obtained from the participants' comments. Four comments were received from global type subjects, who participated in the Second Control group, to the effect that their group's list of items was long and complicated. No similar comments were received from any of the other participants, either in the Global group or the other groups. This information is not unexpected, and when it is coupled with the Global group's attitude improvement and the findings from Chapter 7 it invokes the speculation that Delphi participants may perform better when segregated into separate cognitive style groups during the Delphi data base design process. This speculation appears to be especially warranted as far as the global type of individual is concerned.

Summary

The expectations regarding the effect of having a large number of the potential users of a data base system participate in its development were discussed in terms of the participative management approach. The participants' attitudes were considered to be a good measure of any change that might take place as a result of their participation in the Delphi process; therefore, the manner in which the participative expectations led to the formulation of the hypothesis, that the attitude of all groups would improve as a result of the Delphi process, was discussed. The means of the pre-Delphi and post-Delphi attitude scores for all groups were then subjected to t tests to determine if significant differences existed. It was found that the Entire Delphi group experienced a small positive change in attitude, significant at the .05 level, during the Delphi process. The contributions of the Global and Attitude groups to the overall attitude improvement were discussed in terms of statistical regression toward the mean, which was probably present in the PFDS experiment. The results from the typing and request for copy measures, that were utilized in an attempt to cross-validate the cognitive style and attitude concepts, were disappointing; however, another measure, participant comments, was found to be quite valuable in drawing conclusions regarding the Delphi process. The overall conclusions of the study along with the recommendations for further research are presented in the next chapter.

CHAPTER 10. CONCLUSIONS AND RECOMMENDATIONS

The PFDS data base design experiment was successfully completed, and all of the research objectives of the study were explicitly accomplished. In summarizing these accomplishments, the first section of this chapter presents the conclusions that were reached regarding both the overall Delphi process as well as the influence of cognitive style in the methodology. The second section presents several recommendations for further research that would be beneficial in a widespread application of the Delphi methodology to other data base design problems. Then, the third section brings the conclusions and recommendations together in an explicit summary of the accomplishments of the study, while the fourth section discusses the implications that these conclusions hold for information system design.

Conclusions

The successful completion of the PFDS project in the Texas Highway Department has definitely proven the Delphi process to be a viable method for data base design. Although further refinement of the Delphi procedures is indicated by the PFDS findings, it is felt that the additional development which is required can be carried out simultaneously with actual applications of the method and that the extra development will only serve to enhance the method's attractiveness. The findings of the PFDS study which led to these conclusions are enumerated below:

(1) Successful completion of the PFDS project with a very small drop-out rate of 5.4 percent over the entire process, and a drop-out of only 2.9 percent of those who started the Delphi phase of the project.

(2) Feasible PFDS data base designs that appear to be well thought out and oriented toward the users' needs.

(3) A small improvement, significant at the .05 level, in the attitude of the participants toward the system after having taken part in the Delphi process.

(4) Enthusiastic cooperation of all PFDS participants and their comments regarding the desirability of the Delphi process as a method for data base design.

(5) Participants' repeated comments that the redundancy should be eliminated after each round.

In addition to the conclusions regarding the applicability of the Delphi process in the area of data base design, the PFDS experiment also yielded several interesting findings related to the influence of cognitive style in both the general area of information system design as well as in the application of the Delphi methodology to the data base design problem. A great deal of attention in recent MIS literature (Refs 24, 27, 46, 54, 63, and 66) has been accorded to the possible importance of the cognitive style factor in information system design. The results of the PFDS study support the previous theorizations and research findings. Therefore, it is concluded that cognitive style is a factor that should probably be taken into consideration in future information system design efforts. The cognitive style factor was also found to have a very significant influence in the Delphi methodology for data base design. The specific findings from the PFDS study which relate to these conclusions are listed below:

(1) The number of data items submitted by participants for the initial round of the Delphi process was found to be positively correlated with their cognitive style ($r=.23$, $\alpha = .0005$).

(2) Homogeneous Delphi groups, composed of participants with different cognitive styles, converged to data base designs that were significantly different from one another.

(3) The manner in which Delphi groups are structured, relative to cognitive style, appears to be an important consideration not only in regard to the data base design achieved; but also in regard to the degree to which the subjects are able to participate effectively in the process. The global type of individual appears to function better in a group composed solely of other global types.

Furthermore, it was concluded that, in addition to being a viable method for data base design, the Delphi process provides an effective research methodology for investigating subjects such as the effects of various personal characteristics of potential users on the information needs they specify. In this regard, it is expected that the research methodology might be used to address some of the recommendations for further research that are presented in the next section.

Recommendations

The Delphi methodology for data base design, that was outlined in the preceding chapters, presently offers a fully functional method for handling some types of data base design problems; however, it is felt that the method's usefulness can be enhanced through additional research and development effort. Since the method is fully functional, it is recommended that the majority of this additional research be carried out in the context of actual applications. In this regard, it should be recognized that these applications might be either new data bases that are being considered for implementation or existing data bases that require updating. The dynamic nature of the decisions, that data base systems support, requires that the contents of a data base be periodically reviewed; and the Delphi methodology appears to be an excellent method for involving the system's users in this review. Figure 8 graphically presents the typical life cycle of a data base and illustrates the points in the life cycle where the Delphi methodology is likely to be particularly pertinent. Some of the recommendations for further research that are specified below can probably be carried out in either new or existing applications, while others will definitely require new applications in order to achieve the desired results.

(1) Conduct experiments to determine the best method for eliminating the redundancy that occurs in the Delphi process.

(2) Experiment with various cognitive style groupings and develop methods for combining their data base designs.

(3) Study the possibility of composing the Delphi groups solely of experts in certain functional areas in order to rate certain classes of data items, e.g. Delphi groups composed of concrete pavement experts would only be concerned with concrete pavement data items.

(4) Refine and re-apply the participation measures in order to better determine *when* and toward *what* the participation effect takes place.

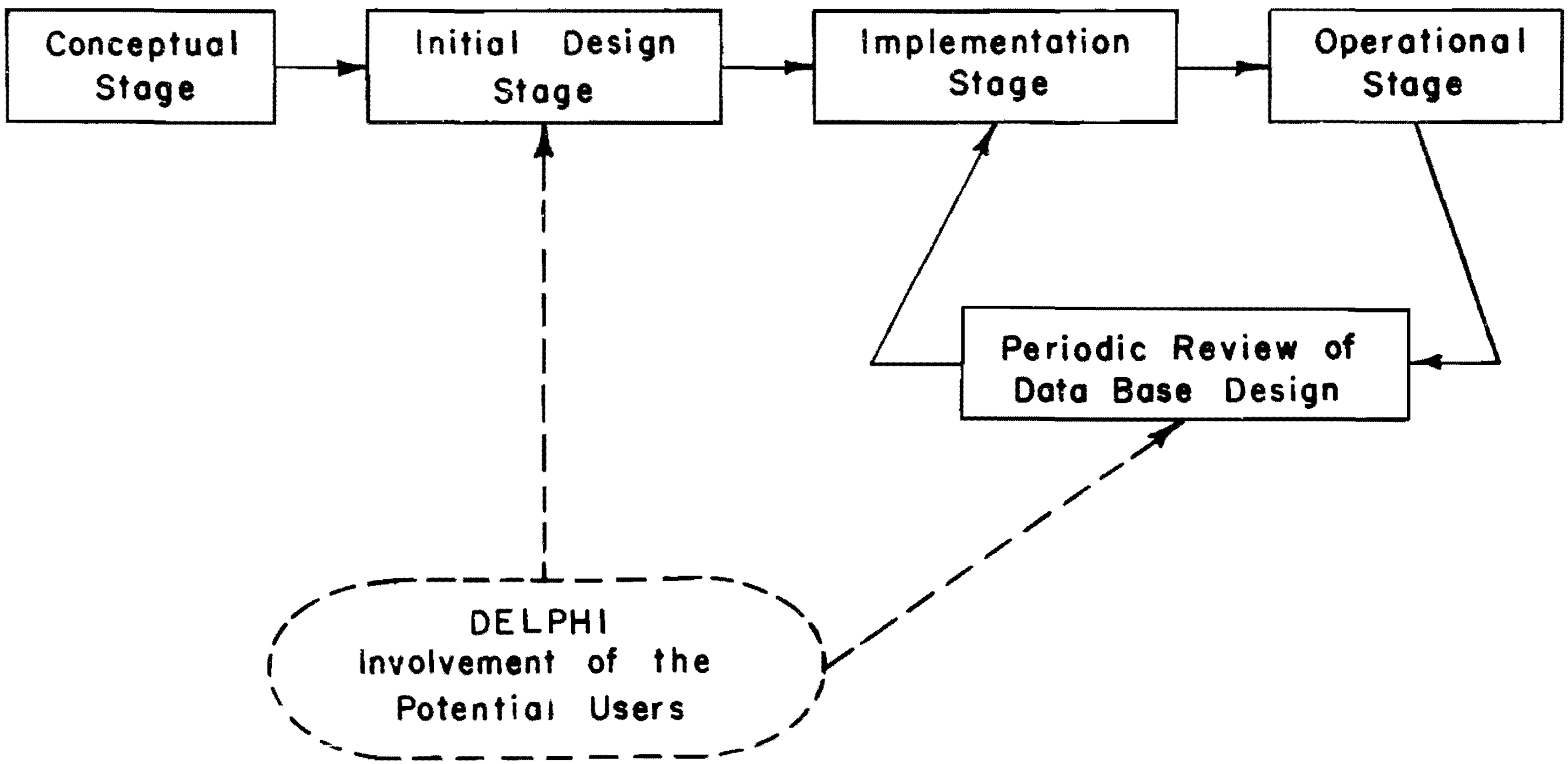

Fig 8. Delphi methodology in the data base life cycle.

(5) Conduct longitudinal studies to determine the effect of cognitive style, initial attitude, and participation on the actual usage of operational systems.

(6) Attempt to develop methods whereby the potential user can be brought further into the design process, e.g. the designation of key vs. non-key and the hierarchical ordering of data elements. Determine if this further involvement adds anything of value to the Delphi method.

Accomplishments

Since several objectives were established at the onset of the study, the accomplishments that were achieved in meeting these objectives are necessarily numerous and diffused. In addition, the importance of the accomplishments may not be apparent to the casual reader. Therefore, a brief summary of what has been accomplished along with an indication of its importance appears to be in order.

The Delphi method has been shown to be extendible from its traditional use as a means for addressing well-structured problems where expert agreement from an established viewpoint guarantees the validity of the information content (*Lockean Inquiry*) to ill-structured problems where expert opinion from multiple viewpoints is the guarantor of the system's validity. This extension allows the Delphi process to be applied to the problem of data base design; and the process thus removes the design problem from the realm of an art, practiced by the systems analyst, to a set of systematic procedures that directly comes to grips with the users' data needs. As with all methods where only one individual's bias is brought to bear on a problem, there is no assurance that a systems analyst's design will achieve a useful representation of the user's needs. However, the Delphi procedures guarantee that a more encompassing representation will be achieved, in those cases where the participants are truly interested in bringing about an agreement. Such a set of systematic procedures has been long needed and repeatedly called for in the MIS literature.

The successful verification of the Delphi methodology's potential through an actual application to a complex, real-life data base in a large, decentralized organization greatly enhances the validity of the conclusion that the methodology represents a viable method for use in the non-technical phase of data base design. Furthermore, the successful involvement of a large number of the potential users of PFDS illustrates that the Delphi process is a method for effectively implementing the user participation in information system design that is so widely called for in the MIS literature.

In addition to establishing a set of functional procedures for data base design the study has also produced a research methodology for investigating the influence of various personal characteristics of potential users on the types of data they prefer. Central to the effectiveness of the research methodology is a procedure for statistically testing differences between data base designs. Both the Delphi research methodology and the statistical procedure should prove to be valuable in subsequent investigations into the effects of various information system variables.

Cognitive style has been postulated in the literature to be an important MIS variable that warrants further research. However, up until now, the concept has only received limited experimental attention; moreover, the experiments that have been performed have usually been conducted in the context of a student population. In addition, the author knows of no previous attempt to examine the concept in terms of its effect on a data base design. Confirmation of the existence of the cognitive style effect in an actual organization is, therefore, of considerable importance; and the fact that the existence of the effect was further verified by an unobtrusive measure also lends a great deal of credence to the finding. These facts establish cognitive style as a factor that should probably be taken into consideration in further research on the Delphi methodology as well as other facets of information system design. The research study described in this report offers a firm foundation upon which these investigations can be built.

Implications

The findings of the PFDS study hold a couple of important implications for the design of data base systems. First, the successful application of the Delphi methodology in the Texas Highway Department indicates that it is possible to develop systematic procedures for the non-technical phase of data base design process. Therefore, further refinement of the

Delphi procedures and/or development of additional design methods is definitely indicated. The systematic procedures that are eventually adopted will undoubtedly have a substantial impact on the future design of data bases and their subsequent use in organizations. Second, the identification of cognitive style as a significant factor in data base design suggests that the failure to consider this variable in design efforts could lead to serious losses in terms of a system's effectiveness and its utilization by all of its potential users. Some organizations may be composed predominantly of participants with a particular cognitive style, and the design of information systems for these organizations may be entirely different than the design of systems for organizations composed predominantly of participants with different cognitive styles. Still other organizations will require the concurrent consideration of a wide range of cognitive styles, e.g. the potential users of PFDS. The point is that ignoring this important variable could create unexpected and possibly undesirable reactions on the part of the users toward the system.

APPENDIX A

INSTRUCTIONS FOR PFDS DATA BASE DESIGN PROJECT

INSTRUCTIONS FOR PFDS DATA BASE DESIGN PROJECT

Retain for Future Reference

Do NOT Return to the Administrator

Because of the inexact and imperfect nature of our present pavement technology, the design and management of pavements is heavily dependent on expert judgment. It is felt that this judgment can be supplemented and possibly improved through the development and implementation of a computerized pavement information system. The Texas Highway Department (THD) approach to the development of such a system is based on the belief that the best source of knowledge about the types of data that should be contained within the system resides with the potential users of the system. As a potential user and/or supplier of data to the system your opinions and expertise are needed for the successful development of the system. Therefore, you have been selected to participate in the design of the data base for the Pavement Feedback Data System (PFDS).

This paper contains a brief description of what PFDS is expected to accomplish, and a description of and instructions for the data base design process in which you will take part. The purpose of this paper is to complement the introduction and instructions that you received during the presentation.

Pavement Feedback Data System

PFDS will be a computerized filing system for the storage and retrieval of large amounts of pavement data. When completely developed and implemented the system will be used by all functional areas in the THD such as administration, design, maintenance, research, etc. The goal of this feedback data system is to supply all levels of pavement personnel with certain physical and cost data in a form convenient for use in managing the pavements within the state. This data may be supplied in the form of regular periodic reports, exception reports triggered by the occurrence of certain events, and print-out resulting from a specific inquiry. Our purpose is to reach an agreement as to what types of data should be maintained in PFDS.

Examples of the types of data items that you may want to be included in PFDS are:

Number of Lanes

Lane Width

Subgrade Soil Type

Annual Average Rainfall

Annual Average Temperature

Material Type for Each Layer

Layer Number

Cost of Subgrade Preparation/Lane Mile

etc.

The data items that are to be included in PFDS can be considered to fall into one of four possible categories:

I. Locational Data

II. Design and Construction Data
    Maintenance Data

III. Input to the Pavement
    Traffic Loading
    Climatic Input

IV. Performance Data

Since a great deal of attention has been previously given to the development of suitable methods for locating a particular point in our pavement network, you are requested to devote the greater portion of your effort to identifying data items that fall in categories II through IV. However, if you feel that certain locational data items are important and are likely to be overlooked, please feel free to include these data items in your responses.

You have been asked to supply your opinions regarding what data items to include in the system. These opinions should be presented even though they concern data items that are presently being collected and stored by other divisions within the THD. This information, on data items that are presently being collected, is necessary since an interface with the existing files will have to be developed. In order to integrate your opinions with those of your colleagues in the THD, you will participate in a technique that facilitates the convergence of individual opinions to a reasoned group consensus.

The Delphi Technique

The Delphi Technique is an iterative process that has traditionally been used to bring about a reasoned agreement amongst a group of experts who possibly hold divergent opinions on the question of interest. The participants are initially requested to present their individual views on the question to an administrator who compiles the various opinions into a group estimate. The information derived from the group is then fedback to each of the participants. The participants are asked to rethink their position in terms of the group estimate and to report their revised opinions to the administrator. This process is continued until convergence to an agreement has been achieved.

It has been shown that by avoiding face to face confrontation a higher quality agreement can be achieved. Spurious influences, such as the presence of a high status individual in the group, are avoided; therefore, the final agreement is based on a more reasoned set of judgments. You are participating in a Delphi group as a part of your contribution to the design of the PFDS data base, and an essential element in the success of this process is the requirement that no extraneous outside interaction take place. Therefore, you are again requested to refrain from discussing this project with anyone until explicitly told to do so by the administrator.

Initial Input

The primary question to be examined in this Delphi process is what data items should be included in the PFDS data base. Your individual opinions on this question are desired in the first round of the Delphi. For the first round, please attempt to report all data items that you think might be important in future pavement decisions. Although you will want to use your present decision making as a guide, it is necessary to remember that PFDS will be used some time in the future. It is important that this future aspect of PFDS be included in your selection of data items.

An automated system has been developed for processing the information flows associated with the Delphi method of designing the PFDS data base. Since your responses will be computer processed, adherence to specific input rules is required. Figure 1, Sample Initial Input Form, provides an example of how your initial data items are to be reported.

The Data Item Descriptor appears on the right-hand side of the form, and it is a word or short expression which you feel adequately describes the particular data item you are referring to. This descriptor must be limited to 60 letters and spaces. If additional identifying information is required you may include this after the 60 letter descriptor. You will probably want to fill in this blank before proceeding to the other items of information that are required for each particular data item. For example, in Figure 1, Number of Lanes, Lane Width, etc. are descriptors for the data items.

The data item descriptor is also used to convey information regarding the frequency with which the data item should be collected. This frequency measure may be of either a spatial or temporal nature. In Figure 2, Cost of Subgrade Preparation/Lane Mile is a data item descriptor which contains a spatial component of information while the Annual Average Rainfall descriptor contains a time reference. Since agreement on the frequency of collection is of primary importance, you are requested to be as explicit as possible in this regard. However, obvious dimensional information such as Annual Average Rainfall in Inches is not required, since it only serves to waste time and space.

The Importance Rating appears on the left-hand side of the form. It is a numerical assessment, on a 0.0 to 5.0 scale, of your opinion of how important it is that the particular data item be included in PFDS. A rating of 0.0 would indicate that you believe the data item to be of absolutely no importance. It is unlikely that you will want to use the 0.0 importance rating on any of the items that you initially specify; however, it is conceivable that you may want to bring a certain item to the attention of the group even though you feel that the item is of no importance. In this case you could use the 0.0 rating.

A rating of 5.0 would be used to express your opinion that it is extremely important the data item be included in PFDS. Other degrees of perceived importance can be expressed by selecting an appropriate number between these extreme values. The following verbal descriptions are given as examples to assist you in determining where you stand in regard to the importance of the data items.

5.0 Imperative that item be included.

4.0 Highly important

3.0 Moderately important.

2.0 Of questionable importance.

1.0 Low importance.

0.0 Absolutely no importance.

The standard format is two significant figures with one figure to the right of the decimal. In Figure 1, Number of Lanes was given an initial importance rating of 2.0, and Material Type for Ea Layer was given a rating of 2.8.

The Expertise Rating is a numerical self evaluation, on a 0.0 to 5.0 scale, of the degree of expertise you bring to the data item under consideration. You are requested not to use the 0.0 rating, unless you strongly feel that you know absolutely nothing whatsoever about the data item in question. If you feel that you possess a low degree of expertise in regard to a particular item, it is suggested that you use a rating such as 0.3 instead of the 0.0 rating. You should rate expertise relative to your function and position in the highway department. Some suggested guidelines for the expertise rating follow:

5.0 One of the more knowledgeable people in the area.

4.0 Good deal of experience and/or training in the area.

3.0 Working directly in the area, but have only light experience or training.

2.0 Out of major functional area, but have some experience, interest, or knowledge of subject.

1.0 Feel unqualified in area.

0.3 Absolutely no experience, training, interest, or knowledge of subject.

In Figure 1, Number of Lanes was given an expertise rating of 0.3, and Material Type for Ea Layer was given a rating of 2.5. It is unlikely that you will want to change your expertise rating on a given item after it has been initially established.

Who Supplies is a coded method for indicating who you perceive to be the source of the data item under consideration. Table 1 lists several possible sources of data along with the integer codes used to designate them. If you have no idea as to who might supply a particular data item, please leave the space under Who Supplies blank. If you use the code 17 designation for a supplier who has not been listed, it is requested that you specify who you have in mind. In Figure 1, both the Number of Lanes and Material Type For Ea Layer are perceived to be supplied by District Design which has a supplier code of 10.

INITIAL INPUT FORM

Name: Robert J. Murphy
Page 1 of 1

Importance rating (0.0 to 5.0)	Expertise rating (0.0 to 5.0)	Who supplies (code)	Data Item Descriptor (60 letters and embedded spaces)
2.0	0.3	10	Number of Lanes
3.0	1.0	10	Lane Width
2.8	2.5	10	Material Type for ea. Layer
3.5	2.5	10	Layer Number

Fig 1. Sample Initial Input Form.

TABLE 1. CODES FOR SUPPLIERS OF DATA

Code	Description
1	D-5 Bridge Division
2	D-6 Construction Division
3	D-8 Highway Design Division
4	D-9 Materials and Test Division
5	D-10 Planning and Research Division
6	D-18 Maintenance Operations Division
7	D-19 Automation Division
8	Resident Engineer or his staff
9	Maintenance Foreman or Supervisor
10	District Design
11	District Laboratory
12	District Headquarters
13	District Construction Office
14	Special Data Collecting Crew - Regionally Based
15	Special Data Collecting Crew - Austin Based
16	National Weather Service
17	Other Specify

Subsequent Iterations

After the initial data items have been submitted, all subsequent communications will be on computer output. Figure 2, Sample Delphi Communication, provides an example of this output. The computer output is very similar in form to the Initial Input; however, the data items it contains are an aggregation of the individual responses of the entire group. You are to handle this form in approximately the same manner as the Initial Input Form since only one item has been added.

The Item Number, which now appears on the left-hand side of the page, has been added to the information contained on the Initial Input Form. This number is automatically assigned, and it is used to simplify the handling of the Delphi information flows. You will never need to be concerned with this number, since it is used entirely for data processing purposes.

The Data Item Descriptor is again located on the right-hand side of the form, and you will now find data items that were defined by other members of your Delphi group included in this list of descriptors. Unless you radically disagree with a descriptor, you will probably not want to change it. However, if it is necessary to change a descriptor, you should assign a 0.0 importance rating along with your regular expertise rating to the descriptor with which you disagree. You may then add your revised descriptor along with its importance and expertise ratings to the end of the printed output. A similar technique is used to distinguish your preference between two very similar data items with differently worded descriptors. When essentially the same data item is described by two or more different descriptors, assign your regular importance rating to the item with the descriptor which you prefer and assign a 0.0 importance rating to the remaining item or items. Be sure to assign your regular expertise rating to all of the items. Should you think of a new data item, i.e. one which is not included in the list, please enter a descriptor along with the other information for the item at the bottom of the printed list. In Figure 2, Layer Thickness, as well as the other information required, has been added before returning the form for the second iteration.

The Importance Rating now reflects the group's opinion of how important the data item is to PFDS. The purpose of Delphi is to have you reconsider your opinion of the data item in terms of the group importance rating. Should you still disagree with the group importance rating, you may want to cross-out the group rating and write your revised rating (0.0 to 5.0) out to the right

DELPHI COMMUNICATION
PLEASE RETURN WITHIN FIVE DAYS

ROBERT J. MURPHY
SUPERVISING DESIGN ENGINEER
TEXAS HIGHWAY DEPARTMENT
11TH AND BRAZOS
AUSTIN, TEXAS 78701

INDIVIDUAL NUMBER 1 ITERATION NUMBER 1

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
5	3.0	.3	10	NUMBER OF LANES
6	3.2	1.0	10	LANE WIDTH
9	4.5	2.0	10	SUBGRADE SOIL TYPE
12	5.0	2.7	5	ANNUAL AVERAGE RAINFALL
14	4.0	2.3	5	ANNUAL AVERAGE TEMPERATURE
15	~~3.0~~ 4.2	2.5	10	MATERIAL TYPE FOR EA LAYER
16	4.5	2.5	10	LAYER NUMBER
17	1.5	2.0	~~10~~ 8	COST OF SUBGRADE PREPARATION/LANE MILE
	4.0	3.0	10	Layer Thickness

Fig 2. Sample Delphi Communication.

side of the group rating. In Figure 2, the importance rating of Material Type For Ea Layer has been changed from 3.0 to 4.2.

Another use of the Importance Rating is to reflect the group's opinion as to the feasibility of collecting and storing the particular data item. It is possible that some participant may introduce a data item, which although desirable, is impractical to collect and/or store. If a data item of this nature is recognized, the infeasibility of the item should be denoted through the assignment of a lower importance rating.

The Expertise Rating, that you assigned to each data item, has been returned to you on the computer output. Since your first subjective feeling about the expertise you bring to an item is likely to be the most accurate, you will probably not want to change this item. Should a change be necessary, simply cross-out your present rating and record your revised estimate out to the right. Changes in your expertise rating are discouraged unless they are clearly necessary.

Those items, which you have not previously seen, that were submitted by other members of the group have a blank expertise rating. You should enter your estimate of the expertise you bring to the particular item directly in the blank space. Please use the standard 0.0 to 5.0 scale, and remember that a rating such as 0.3 is preferred for the expression of a low degree of expertise. Be sure to fill in all of the blank expertise spaces. Include an expertise rating even if you perceive the item as being of no importance or feel that the descriptor needs to be replaced by a better descriptor. In Figure 2, the blank expertise space for the Annual Average Rainfall data item has been filled in with a 2.7 expertise rating.

The Who Supplies code now reflects the group's opinion of who is responsible for supplying the given data item. If you disagree with the group appraisal, you may cross-out the code and enter a new code from Table 1 for the supplier you feel is most likely to be involved with the particular data item. Remember this is an optional item. If you have no idea as to who might supply a particular data item, please leave this space blank. In Figure 2, the Who Supplies Code for the Cost of Subgrade Preparation/Lane Mile data item has been changed to Code 8.

Optional Information

In addition to the Who Supplies code, there are three additional items of optional information. Unless you specify otherwise, it is assumed that you are in agreement that a particular data item will be collected extensively. However, if you feel that a sample of information for a particular data item will be adequate, you may indicate this fact by writing SAMPLE in the data descriptor blank after the descriptor. If your Importance Rating on a particular item deviates substantially from the group's, and you cannot in good conscience conform to the group rating, you may include your reasons for your judgment and the sources of information you used in making this judgment. This information should be included on a separate sheet and be identified by the data descriptor. The information will be supplied to the group on the next iteration.

Summary

For the Initial Input:

(a) Specify a descriptor for each data item you wish to enter.

(b) Assign an importance rating to the item using the 0.0 to 5.0 scale.

(c) Assign your expertise rating using the 0.3 to 5.0 scale.

(d) Indicate your perception of who will supply the data item by assigning the appropriate code from Table 1.

For subsequent iterations:

Please review the Delphi Communication and reconsider your opinion in light of the group response. Indicate your disagreement with any item of information by crossing the item out and entering a new value. Be sure to fill in all blank expertise spaces, and write any new items you may have thought of at the bottom of the list.

If you have any questions regarding the operation of this process, please contact the administrator listed below at any time.

Ronald R. Bush
Center for Highway Research
Room 317 Engineering Science Building
The University of Texas at Austin
Austin, Texas 78712

Phones:
512/471-4433 Tex-An
476-5708 821-4433

APPENDIX B

DELPHI PROGRAM

```
          PROGRAM DELPHI (INPUT,OUTPUT,PUNCH,ADDR,TAPE5=INPUT,TAPE1=ADDR,TAP
         1E2)
000002    DIMENSION INDIV(11),NM(11),TV(11),IWS(1350,2),A(1350,5),A1(1350),V
         1AR(1350),RIA(1350),ERA(1350),JITM(5),FIR(5),FER(5),IIW(5),RPU(5),E
         2PU(5),IWPU(5),ITMPU(5)
000002    INTEGER RI(1350,2),ER(1350,2),ADDR(11,14),PACKC(14)
000002    INTEGER IFILE(21)
000002    DATA IFILE/2LF1,2LF2,2LF3,2LF4,2LF5,2LF6,2LF7,2LF8,2LF9,3LF10,3LF1
         11,3LF12,3LF13,3LF14,3LF15,3LF16,3LF17,3LF18,3LF19,3LF20,3LF21/
        C
        C     READ CARDS FROM FILE ADDR
        C
000002    READ (1,200) NITM
000010    DO 1 I=1,NITM
000012 1001 READ (1,103) KEY,I1,BLNK,AX,AY,(A(I,J),J=1,5),A1(I),AZ
000044    IF (I1.GT.0) GO TO 1001
000047    IF (EOF,1) 9999,1
000051  1 CONTINUE
000054 1002 READ (1,103) KEY,I1
000064    IF (I1.GT.0) GO TO 1002
000067    IF (EOF,1) 99,9999
000071 9999 PRINT 1000
000075 1000 FORMAT (1H1,*WRONG NUMBER OF ITEMS ON FILE ADDR*)
000075    GO TO 999
000076   99 CONTINUE
        C
        C     READ INPUT
        C
000076    READ 101,COM,INDIV(11),BLNK,(ADDR(11,J),J=1,14)
000117   90 READ 100,NGRP,NI,NITER,IOPT,RIHI,VRLO
000137    IF (EOF,5) 999,91
000142   91 CONTINUE
000142    REWIND 2
000144    ITRPU=NITER+1
        C     ZERO ALL VARIABLES
000146    DO 3 I=1,1350
000150    DO 2 J=1,2
000160    IWS(I,J)=0
000161    RI(I,J)=0
000161    ER(I,J)=0
000161    2 CONTINUE
000164    VAR(I)=0.0
000164    RIA(I)=0.0
000165    ERA(I)=0.0
000166    3 CONTINUE
        C     READ NAME AND ADDRESS CARDS FOR THE GROUP
000167    DO 4 I=1,NI
000171    READ 101,COM,INDIV(I),BLNK,(ADDR(I,J),J=1,14)
000212    4 CONTINUE
000215    PRINT 154
000220    I=1
000221    5 READ 104,IN,ITR,JITM(1),FIR(1),FER(1),IIW(1),JITM(2),FIR(2),FER(2)
         1,IIW(2),JITM(3),FIR(3),FER(3),IIW(3),JITM(4),FIR(4),FER(4),IIW(4),
         2JITM(5),FIR(5),FER(5),IIW(5)
000301    IF (IN.EQ.999) GO TO 8
000303    6 IF (IN.NE.INDIV(I)) I=I+1
000307    IF (I.LE.NI) GO TO 7
000312    PRINT 105
```

```
000315          GO TO 999
000316        7 PRINT 156,IN,ITR,JITM(1),FIR(1),FER(1),IIW(1),JITM(2),FIR(2),FER(2)
               1),IIW(2),JITM(3),FIR(3),FER(3),IIW(3),JITM(4),FIR(4),FER(4),IIW(4)
               2,JITM(5),FIR(5),FER(5),IIW(5)
000377          IN1=IN/10
000402          IN1=IN1*10
000404          JY=IN-IN1
000404          JZ=IN-IN1+1
000406          IX=1
000407          IF (JZ.GT.5) IX=2
000413          IF (IX.GT.1) JZ=JZ-5
000416          IF (IX.GT.1) JY=JY-5
000421          JA=JZ*2
000422          JB=JY*2
000423          JP1=10**JA
000427          JP2=10**JB
000433          IKC=JY*2
000434          IZC=1
000436     1007 IF (JITM(IZC).EQ.0) GO TO 5
000444          ITEM=JITM(IZC)
000445          R=FIR(IZC)
000446          E=FER(IZC)
000450          IW=IIW(IZC)
000451          JRC=RI(ITEM,IX)/JP1
000455          JRC=JRC*JP1
000457          JR=RI(ITEM,IX)-JRC
000460          JR=JR/JP2
000465          IF (JR.EQ.0) GO TO 1008
000466          IZC=IZC+1
000467          IF (IZC.GT.5) GO TO 5
000472          GO TO 1007
000501     1008 RIA(ITEM)=RIA(ITEM)+R*E
000503          ERA(ITEM)=ERA(ITEM)+E
000505          IR=R*10.0
000506          IE=E*10.0
000510          IK=(10**IKC)*IR
000512          IL=(10**IKC)*IE
000514          IM=(10**IKC)*IW
000516          RI(ITEM,IX)=RI(ITEM,IX)+IK
000520          ER(ITEM,IX)=ER(ITEM,IX)+IL
000522          IWS(ITEM,IX)=IWS(ITEM,IX)+IM
000524          IZC=IZC+1
000526          IF (IZC.GT.5) GO TO 5
000531          GO TO 1007
000531        8 CONTINUE
          C
          C     CALCULATE IMPORTANCE RATING,VARIANCE, AND WHO SUPPLIES
          C
000531          ITMC=0
000532          DO 14 I=1,NITM
000534          IF (ERA(I).LE.0.0) GO TO 9
000536          RIA(I)=RIA(I)/ERA(I)
000540        9 CONTINUE
000540          IF (RIA(I).GT.0.0) ITMC=ITMC+1
000544          SQ=0.0
000545          DO 11 K=1,NI
000556          IN=INDIV(K)
000557          IN1=IN/10
```

```
000563          IN1=IN1*10
000564          JZ=IN-IN1+1
000566          IX=1
000566          IF (JZ.GT.5) IX=2
000571          IF (IX.GT.1) JZ=JZ-5
000574          JA=JZ*2
000575          JP=10**JA
000601          JRC=RI(I,IX)/JP
000605          JTW=IWS(I,IX)/JP
000610          JRC=JRC*JP
000612          JIW=JIW*JP
000614          JR=RI(I,IX)-JRC
000615          JW=IWS(I,IX)-JIW
000616          JB=(JZ-1)*2
000620          JP=10**JB
000624          JR=JR/JP
000627          JW=JW/JP
000632          R=JR/10.0
000634          SQ=SQ+(R-RIA(I))**2
000637          IV(K)=JW
000637       11 CONTINUE
000642          VAR(I)=SQ/(NI-1)
000647          DO 12 L=1,NI
000650          NM(L)=0
000651          DO 12 M=1,NI
000664          IF (IV(L).EQ.0) GO TO 12
000665          IF (IV(L).EQ.IV(M)) NM(L)=NM(L)+1
000670       12 CONTINUE
000674          LTST=1
000674          NMTST=-1
000676          DO 13 L=1,NI
000703          IF (NMTST.GE.NM(L)) GO TO 13
000705          NMTST=NM(L)
000706          LTST=L
000707       13 CONTINUE
000710          IWS(I,1)=IV(LTST)
000713       14 CONTINUE
           C
           C    SORT IMPORTANCE RATING
           C
000715          DO 15 IB=1,NITM
000723          IWS(IB,2)=IB
000724          ERA(IB)=RIA(IB)
000725       15 CONTINUE
000726          KC=10**4
000730          DO 17 IC=1,NITM
000731          IG=IC
000731          ZMAX=-0.1
000733          DO 16 ID=IG,NITM
000741          IF (ERA(ID).LE.ZMAX) GO TO 16
000743          ZMAX=ERA(ID)
000744          JD=ID
000745       16 CONTINUE
000753          IP=IWS(IC,2)
000753          IQ=IWS(JD,2)/KC
000757          IQ=IQ*KC
000760          IQ=(IWS(JD,2)-IQ)*KC
000762          IWS(IC,2)=IWS(IC,2)+IQ
```

```
000763          ERA(JD)=ERA(IC)
000764          ERA(IC)=ZMAX
000766          IWS(JD,2)=IWS(JD,2)/KC
000771          IWS(JD,2)=(IWS(JD,2)*KC)+IP
000775       17 CONTINUE
000777          DO 47 IY=1,NITM
001005          IWS(IY,2)=IWS(IY,2)/KC
001010       47 CONTINUE
          C
          C     PRINT OUTPUT RANKED ON IMPORTANCE
          C
001011          IPP=1
001011          ILINE=2
001013          PRINT 210,IPP
001020          PRINT 506,NITER,INDIV(1),INDIV(NI),ITMC
001034          PRINT 600
001040          DO 20 J=1,NITM
001042          ID=IWS(J,2)
001043          IF (RIA(ID).LE.0.0) GO TO 20
001046          IF (ILINE.GT.17) GO TO 18
001051          ILINE=ILINE+1
001052          GO TO 19
001052       18 IPP=IPP+1
001054          PRINT 210,IPP
001061          PRINT 600
001065          ILINE=1
001066       19 PRINT 102,ID,RIA(ID),VAR(ID),IWS(ID,1),(A(ID,IA),IA=1,5),A1(ID)
001114       20 CONTINUE
          C
          C     PRINT OUTPUT FOR PARTICIPANTS
          C
          C     PRINT ADMINISTRATOR COPY
001117          DO 21 I=1,14
001126          PACKC(I)=ADDR(11,I)
001127       21 CONTINUE
001130          IPP=1
001131          ILINE=6
001132          PRINT 210,IPP
001140          PRINT 106
001144          CALL PLINE(PACKC)
001146          PRINT 306,INDIV(1),NITER
001156          PRINT 406
001162          DO 26 J=1,NITM
001164          IN=INDIV(1)
001166          IN1=IN/10
001171          IN1=IN1*10
001172          JZ=IN-IN1+1
001173          IX=1
001174          IF (JZ.GT.5) IX=2
001200          IF (IX.GT.1) JZ=JZ-5
001206          JA=JZ*2
001206          JP=10**JA
001212          JE=ER(J,IX)/JP
001215          JE=JE*JP
001217          JE=ER(J,IX)-JE
001217          JB=(JZ-1)*2
001221          JP=10**JB
001225          JE=JE/JP
```

```
001230          E=JE/10.0
001232          IF (RIA(J).GT.RIHI) GO TO 22
001236          IF (VAR(J).LE.VRLO) GO TO 26
001240       22 WRITE (2,501) J,RIA(J)
001250          IF (ILINE.GT.17) GO TO 23
001254          ILINE=ILINE+1
001255          GO TO 24
001255       23 IPP=IPP+1
001257          PRINT 210,IPP
001264          PRINT 406
001270          ILINE=1
001271       24 IF (E.EQ.0.0) GO TO 25
001272          PRINT 107,J,RIA(J),E,IWS(J,1),(A(J,IA),IA=1,5),AI(J)
001320          GO TO 26
001321       25 PRINT 207,J,RIA(J),IWS(J,1),(A(J,IB),IB=1,5),AI(J)
001345       26 CONTINUE
001350          END FILE 2
001352          I=NGRP
001354          CALL RENAME (5LTAPE2,IFILE(I),IRC)
001357          IF (IRC.NE.0) GO TO 998
001360          CALL SAVEPF (4L5023,IFILE(I),4L5062,IRC)
001364          IF (IRC.NE.0) GO TO 997
001365          IF (IOPT.LE.0) GO TO 90
       C        PRINT COPIES FOR GROUP MEMBERS
001367          DO 33 I=1,NI
001370          DO 27 K=1,14
001377          PACKC(K)=ADDR(I,K)
001400       27 CONTINUE
001402          IN=INDIV(I)
001404          IN1=IN/10
001407          IN1=IN1*10
001410          JZ=IN-IN1+1
001412          IX=1
001413          IF (JZ.GT.5) IX=2
001416          IF (IX.GT.1) JZ=JZ-5
001421          JA=JZ*2
001422          JP=10**JA
001426          JB=(JZ-1)*2
001430          JP1=10**JB
001434          IPP=1
001435          ILINE=6
001436          PRINT 210,IPP
001444          PRINT 106
001450          CALL PLINE(PACKC)
001452          PRINT 306,INDIV(I),NITER
001462          PRINT 406
001466          IPU=1
001467          DO 48 IZ=1,5
001475          RPU(IZ)=0.0
001476          EPU(IZ)=0.0
001476          IWPU(IZ)=0
001476          ITMPU(IZ)=0
001477       48 CONTINUE
001500          DO 32 J=1,NITM
001501          JE=ER(J,IX)/JP
001511          JE=JE*JP
001513          JE=ER(J,IX)-JE
001514          JE=JE/JP1
```

```
001516         E=JE/10.0
001520         IF (RIA(J).GT.RIHI) GO TO 28
001525         IF (VAR(J).LE.VRLO) GO TO 32
001527      28 IF (ILINE.GT.17) GO TO 29
001533         ILINE=ILINE+1
001534         GO TO 30
001534      29 IPP=IPP+1
001536         PRINT 210,IPP
001543         PRINT 406
001547         ILINE=1
001550      30 IF (E.EQ.0.0) GO TO 31
001551         PRINT 107,J,RIA(J),E,IWS(J,1),(A(J,IA),IA=1,5),A1(J)
001577         GO TO 34
001600      31 PRINT 207,J,RIA(J),IWS(J,1),(A(J,IB),IB=1,5),A1(J)
001624      34 RPU(IPU)=RIA(J)
001627         EPU(IPU)=E
001630         IWPU(IPU)=IWS(J,1)
001632         ITMPU(IPU)=J
001633         IPU=IPU+1
001634         IF (IPU.LE.5) GO TO 32
001636         PUNCH 104,INDIV(I),ITRPU,ITMPU(1),RPU(1),EPU(1),IWPU(1),ITMPU(2),R
              1PU(2),EPU(2),IWPU(2),ITMPU(3),RPU(3),EPU(3),IWPU(3),ITMPU(4),RPU(4
              2),EPU(4),IWPU(4),ITMPU(5),RPU(5),EPU(5),IWPU(5)
001716         IPU=1
001717         DO 49 IZ=1,5
001725         RPU(IZ)=0.0
001726         EPU(IZ)=0.0
001726         IWPU(IZ)=0
001726         ITMPU(IZ)=0
001727      49 CONTINUE
001730      32 CONTINUE
001733         IPU=IPU-1
001734         IF (IPU.EQ.1) GO TO 51
001735         IF (IPU.EQ.2) GO TO 52
001737         IF (IPU.EQ.3) GO TO 53
001740         IF (IPU.EQ.4) GO TO 54
001742         GO TO 33
001742      51 PUNCH 701,INDIV(I),ITRPU,ITMPU(1),RPU(1),EPU(1),IWPU(1)
001762         GO TO 33
001763      52 PUNCH 702,INDIV(I),ITRPU,ITMPU(1),RPU(1),EPU(1),IWPU(1),ITMPU(2),R
              1PU(2),EPU(2),IWPU(2)
002013         GO TO 33
002014      53 PUNCH 703,INDIV(I),ITRPU,ITMPU(1),RPU(1),EPU(1),IWPU(1),ITMPU(2),R
              1PU(2),EPU(2),IWPU(2),ITMPU(3),RPU(3),EPU(3),IWPU(3)
002054         GO TO 33
002055      54 PUNCH 704,INDIV(I),ITRPU,ITMPU(1),RPU(1),EPU(1),IWPU(1),ITMPU(2),R
              1PU(2),EPU(2),IWPU(2),ITMPU(3),RPU(3),EPU(3),IWPU(3),ITMPU(4),RPU(4
              2),EPU(4),IWPU(4)
002125      33 CONTINUE
002130         GO TO 90
          C    ONLY FORMATS FOLLOW
002130     100 FORMAT (3I3,I2,F4.1,F6.2)
002130     101 FORMAT (A10,I5,A5,6A10/8A10)
002130     102 FORMAT (1H0,5X,I4,9X,F3.1,9X,F6.2,9X,I2,7X,5A10,A6/)
002130     103 FORMAT (I4,I1,A5,A5,A5,5A10,A6,A4)
002130     104 FORMAT (I3,I2,5(I5,1X,F3.1,1X,F3.1,I2))
002130     105 FORMAT (1H1,//10X*CHECK INPUT FOR ERRORS*)
002130     106 FORMAT (1H ,//56X*DELPHI COMMUNICATION*/51X*PLEASE RETURN WITHIN F
```

```
               1IVE DAYS*//)
002130      107 FORMAT (1H0,5X,I4,9X,F3.1,12X,F3.1,9X,I2,7X,5A10,A6/)
002130      154 FORMAT (1H1)
002130      156 FORMAT (1H ,2I4,5(I7,2F6.1,I3))
002130      200 FORMAT (I4)
002130      207 FORMAT (1H0,5X,I4,9X,F3.1,24X,I2,7X,5A10,A6/)
002130      210 FORMAT (1H1,120X,*PAGE *,I3)
002130      306 FORMAT (1H ,4X,*INDIVIDUAL NUMBER*,I4,3X,*ITERATION NUMBER*,I3)
002130      406 FORMAT (1H ,//15X*IMPORTANCE*5X*EXPERTISE*6X*WHO*/6X*ITEM*6X*RATIN
               1G*9X*RATING*5X*SUPPLIES*10X*DATA ITEM DESCRIPTOR*/5X*NUMBER*3X*(0.
               20 TO 5.0)*3X*(0.3 TO 5.0)*3X*(CODE)*5X*(60 LETTERS AND EMBEDDED BL
               3ANKS)*/)
002130      501 FORMAT (I4,F6.3)
002130      506 FORMAT (1H ,//57X*DELPHI IMPORTANCE RANKING*/46X*FOR ITERATION *,1
               2I3,*    INDIVIDUALS *,I3,* THROUGH *,I3,28X,*N=*,I4//)
002130      600 FORMAT (1H ,15X*IMPORTANCE*5X*VARIANCE*7X*WHO*/6X*ITEM*7X*RATING*
               29X*RATING*5X*SUPPLIES*10X*DATA ITEM DESCRIPTOR*/5X*NUMBER*3X*(0.0
               3TO 5.0)*2X*(0.0 TO 25.0)*3X*(CODE)*5X*(60 LETTERS AND EMBEDDED BLA
               4NKS)*///)
002130      601 FORMAT (1H1,*INVALID RETURN CODE FOR RENAME TAPE2*)
002130      602 FORMAT (1H1,*INVALID RETURN CODE FOR SAVEPF*,I3)
002130      701 FORMAT (I3,I2,I5,1X,F3.1,1X,F3.1,I2)
002130      702 FORMAT (I3,I2,2(I5,1X,F3.1,1X,F3.1,I2))
002130      703 FORMAT (I3,I2,3(I5,1X,F3.1,1X,F3.1,I2))
002130      704 FORMAT (I3,I2,4(I5,1X,F3.1,1X,F3.1,I2))
002130      997 PRINT 602,IRC
002136          GO TO 999
002137      998 PRINT 601
002143      999 STOP
002145          END
000200
```

```
      SUBROUTINE PLINE(PACKC)
      INTEGER CHAR(140),PACKC(14),NCHAR(140),L(5),P(5),FMT(10)
     +        ,FMT1(10),FMT2(10)
      NCOUNT=1
      DO 110 I=1,14
  110 CALL SPREADH(PACKC(I),CHAR(I*10-9))
      LL=1
      DO 111 I=1,140
      IF(CHAR(I).NE.1R/)GO TO 115
      L(LL)=I-P(LL-1)-1
      P(LL)=I
      IF(LL.EQ.1)L(LL)=I-1
      LL=LL+1
      GO TO 111
  115 NCHAR(NCOUNT)=CHAR(I)
      NCOUNT=NCOUNT+1
  111 CONTINUE
      L(LL)=140-P(LL-1)
      ENCODE(50,112,FMT1)(L(I),I=1,LL)
  112 FORMAT(5(*,/,5X,*,I2,*R1*))
      ENCODE(15,113,FMT2)LL
  113 FORMAT(6H(*(/*,,I1,8HA10,*)*))
      ENCODE(53,FMT2,FMT)(FMT1(I),I=1,LL)
      PRINT FMT,(NCHAR(I),I=1,NCOUNT)
      RETURN
      END
```

APPENDIX C

PFDS GROUP PRINTOUTS

DELPHI COMMUNICATION
PLEASE RETURN WITHIN FIVE DAYS

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INDIVIDUAL NUMBER 40   ITERATION NUMBER 3

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
30	4.7	1.0	10	CLASSIFICATION OF HIGHWAY (FAI,FAP,FAS,ETC)
61	3.6	2.0	10	NUMBER OF LANES
66	3.6	3.0	10	LANE WIDTH
89	3.1	1.0	1	TYPE OF BRIDGES ON JOB
90	4.0	2.0	1	BRIDGE WIDTH
91	2.9	1.0	10	LENGTH OF EACH BRIDGE
98	3.2	3.0	10	SHOULDER WIDTH
107	3.5	3.0	10	TYPE OF SHOULDER SURFACING
133	3.4	4.0	12	BASIC PAVEMENT TYPE
135	4.5	3.0	10	PAVEMENT THICKNESS OVERALL
140	4.8	4.0	10	PREDICTED PAVEMENT LIFE
141	3.5	4.0	9	PREDICTED LIFE OF PAVEMENT SURFACE

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
211	4.6	3.0	10	NUMBER OF LAYERS
212	3.0	2.5	10	SEQUENCE OF LAYERED CONSTRUCTION
213	3.0	3.0	10	LAYER NUMBER
217	4.7	3.0	10	THICKNESS - LAYER
219	3.7	2.0	10	STABILIZATION TYPE - LAYER
220	3.6	2.0	10	AMOUNT OF STABILIZER - LAYER
224	4.0	3.0	10	MATERIAL TYPE - LAYER
284	4.8	2.0	11	OPTIMUM MOISTURE DENSITY BY LAYERS
314	4.0	4.0	9	ELEVATION OF PAVEMENT IN RELATION TO NATURAL GROUND
334	4.0	2.0	10	SPECIFICATION ITEM USED FOR SUBGRADE PREPARATION
335	4.6	3.5	11	SUBGRADE SOIL TYPE-SUBGRADE MATERIAL
343	4.2	3.0	11	TYPE OF SUBGRADE PREPARATION
344	4.0	2.0	10	TYPE OF STABILIZATION - SUBGRADE
345	4.8	2.0	10	SUBGRADE STABILIZATION - DEPTH
350	4.8	3.0	11	COMPACTION EFFORT ON SUBGRADE
360	4.0	2.0	12	SUBGRADE TRIAXIAL CLASS/RAW
384	3.0	1.0	11	SUBBASE SOIL TYPE
418	4.5	2.5	10	TYPE OF BASE

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
419	3.0	2.0	10	NUMBER OF LAYERS - BASE
420	4.6	3.0	10	BASE THICKNESS
422	4.0	3.0	10	BASE THICKNESS - SHOULDER
424	4.9	3.0	9	FLEX BASE - DEPTH
426	3.2	2.0	11	BASE TREATMENT
427	4.0	2.0	8	TYPE OF STABILIZATION - BASE
435	3.8	3.0	11	BASE MATERIAL
437	4.0	3.0	10	TYPE OF BASE MATERIAL - SHOULDER
477	3.6	2.5	10	TYPE OF SURFACING
491	3.9	1.0	5	CONCRETE PAVEMENT THICKNESS
500	2.5	1.0	10	CONCRETE PVT DESIGN MIX
561	3.0	1.0	8	SURFACE TEXTURE OF CONCRETE PVT
591	4.0	1.0	4	TYPE OF STEEL
626	4.8	.3	10	ACP PAVING DESIGN
637	4.2	4.0	10	ASPHALT TYPE
639	3.8	3.0	10	TYPE OF ASPHALT MATL USED FOR PRIME COAT
649	4.7	3.0	10	AGGREGATE TYPE
654	4.7	3.0	10	AGGREGATE GRADE

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
659	4.3	2.0	9	SURFACE AGGREGATE POLISH VALUE
757	4.0	3.0	10	OVERLAY TYPE
782	3.1	1.0	12	SOURCE OF FUNDS
783	3.1	1.0	13	TOTAL PROJECT COST
784	3.1	1.0	13	AMOUNT OF CONTRACT (DOLLARS)
785	3.0	1.0	12	PROJECT OVERRUNS AND METHOD OF FINANCING
786	3.0	1.0	12	FUTURE PROGRAM FUNDS OBLIGATED TO OVERRUNS
787	2.0	1.0	17	RIGHT-OF-WAY COST PER ACRE
792	4.0	1.0	10	COST PER LANE MILE OF CONSTRUCTION
800	4.0	1.0	10	LABOR COST - CONSTRUCTION
809	3.2	1.0	8	COST OF SUBGRADE PREPARATION/LANE MILE
817	3.5	1.0	8	COST OF BASE/LANE MILE -TRAFFIC LANE
821	3.0	1.0	8	COST OF BASE PREPARATION/LANE MILE
825	3.0	1.0	8	COST OF SURFACE/LANE MILE
854	3.6	3.0	12	MAINTENANCE COST PER LANE MI. PER YEAR
862	2.5	3.0	17	ANNUAL MAINT COST OF TRAFFIC LANES SURFACE/LANE MILE
867	2.6	4.0	9	COST OF ROADSIDE MAINT/MILE
917	3.5	2.0	13	STATEMENT OF PROBLEMS DURING CONSTRUCTION

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.0 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
919	3.0	1.0	4	TEST REPORTS ON MATERIALS USED FOR CONSTRUCTION
922	4.0	3.5	5	TEMPERATURE DURING PAVING
933	3.2	3.0	5	ANNUAL AVERAGE TEMPERATURE
935	3.0	3.0	16	MONTHLY AVERAGE TEMPERATURE
959	4.0	3.0	16	AVERAGE NUMBER OF FREEZE-THAW CYCLES PER YEAR
964	4.0	4.0	5	ANNUAL AVERAGE RAINFALL
966	3.0	3.0	16	MONTHLY AVERAGE RAINFALL
969	3.6	3.0	5	DIFFERENCE BETWEEN MAX AND MIN MONTHLY RAINFALL.
992	4.0	2.0	5	PREDICTED TRAFFIC LOADS (18K EQUIV)
1010	4.0	1.0	5	LOAD FREQUENCY DESIGN FACTOR
1011	3.0	1.0	5	AVERAGE WEIGHT OF TRUCK TRAFFIC
1013	4.8	1.0	5	TRAFFIC LOAD
1015	4.3	1.0	10	MAXIMUM TOTAL LOAD
1016	4.0	1.0	5	ATHWLD (AVERAGE TEN HEAVIEST WHEEL LOADS DAILY)
1034	4.8	1.0	5	DESIGN VOLUME
1042	3.8	1.0	5	CURRENT ADT
1051	3.5	1.0	5	PERCENT TRUCKS IN AADT
1059	4.0	1.0	3	DESIGN SPEED

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
1068	3.0	2.0	13	ANNUAL INSPECTION DESCRIPTION
1092	4.7	2.0	15	ROUGHNESS MEASUREMENT - AVG OF EA PROJECT-ANNUALLY
1114	4.7	2.0	15	SKID NUMBER OF SURFACE - ANNUALLY
1151	4.0	2.0	11	CRACK SPACING PATTERN -SAMPLE- UNIFORMITY AND SPACING
1260	3.3	2.0	5	ACCIDENT FREQUENCY

DELPHI COMMUNICATION
PLEASE RETURN WITHIN FIVE DAYS

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INDIVIDUAL NUMBER 120   ITERATION NUMBER 3

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
2	4.1	2.0	12	CONTROL
3	4.1	2.0	12	SECTION
4	4.3	4.0	12	COUNTY
5	4.3	4.0	12	HIGHWAY NUMBER
9	4.8	2.0	12	MAINTENANCE SECTION
12	3.5	1.0	12	LENGTH OF SEGMENT
29	4.8	2.0	12	TYPE OF FACILITY (URBAN - RURAL)
32	4.2	3.0	8	RIGHT OF WAY WIDTH
42	2.0	1.0	11	USE OF ADJOINING GROUND
61	4.4	4.0	10	NUMBER OF LANES
64	.2	2.0	10	LANE NUMBER
66	4.4	4.0	10	LANE WIDTH

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
78	3.3	4.0	10	TYPE OF MEDIAN (RAISED.FLUSH.DEPRESSED)
79	2.7	2.0	10	TYPE OF MEDIAN BARRIER
80	5.0	2.0	10	MEDIAN WIDTH
96	4.8	4.0	10	TYPE OF SHOULDER
98	4.6	4.0	8	SHOULDER WIDTH
107	5.0	4.0	10	TYPE OF SHOULDER SURFACING
108	5.0	3.0	10	THICKNESS OF SHOULDER SURFACING
118	5.0	1.0	8	MATERIAL TYPE FOR LANE EDGE LATERAL SUPPORT
119	5.0	1.0	11	STAGE CONSTRUCTION INFORMATION
123	2.2	1.0	11	ALLOWABLE CONSTRUCTION INTERFERENCE TO TRAFFIC
133	5.0	1.0	13	BASIC PAVEMENT TYPE
135	5.0	2.0	10	PAVEMENT THICKNESS OVERALL
140	5.0	1.0	10	PREDICTED PAVEMENT LIFE
145	4.0	2.0	12	CROWN WIDTH
147	3.5	1.0	12	DEGREE OF CURVES
152	4.6	1.0	8	HORIZONTAL ALIGNMENT
153	5.0	1.0	8	VERTICAL ALIGNMENT
159	3.8	1.0	11	PROFILE GRADE LINE

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
175	5.0	1.0	12	TOPOGRAPHY
176	4.3	1.0	11	PREDOMINANT GEOLOGIC FORMATION
183	4.4	3.0	8	DRAINAGE CONDITIONS
185	4.3	1.0	9	DRAINAGE ADEQUACY
204	4.7	1.0	8	ACCESSABILITY OF SURFACE WATER TO BASE
206	3.7	1.0	13	MONTH AND YEAR OF CONSTRUCTION - LAYER
211	4.0	1.0	10	NUMBER OF LAYERS
212	2.6	1.0	11	SEQUENCE OF LAYERED CONSTRUCTION
217	4.3	2.0	10	THICKNESS - LAYER
219	4.3	2.0	11	STABILIZATION TYPE - LAYER
220	4.3	2.0	11	AMOUNT OF STABILIZER - LAYER
224	4.1	2.0	10	MATERIAL TYPE - LAYER
243	3.8	4.0	11	METHOD OF COMPACTION - LAYER
264	4.3	1.0	8	PHYSICAL QUALITIES OF MATERIALS - LAYER
268	3.9	1.0	11	LAYER TRIAXIAL CLASSIFICATION
299	4.3	1.0	11	CAPILLARY POTENTIAL EXHIBITED BY LAYERS
334	3.7	3.0	11	SPECIFICATION ITEM USED FOR SUBGRADE PREPARATION
335	4.8	3.0	11	SUBGRADE SOIL TYPE-SUBGRADE MATERIAL

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
336	4.4	1.0	11	SUBGRADE CLASSIFICATION
342	4.2	1.0	11	SPECIFICATION ITEM USED FOR STABILIZING MATL
343	4.2	2.0	8	TYPE OF SUBGRADE PREPARATION
344	5.0	3.0	11	TYPE OF STABILIZATION - SUBGRADE
359	3.0	1.0	11	SUBGRADE STIFFNESS COEFFICIENT
360	4.1	1.0	11	SUBGRADE TRIAXIAL CLASS/RAW
361	4.3	1.0	10	SUBGRADE TRIAXIAL CLASS/TREATED
362	3.3	1.0	11	SUBGRADE MODULUS
367	2.1	1.0	11	AVG PI OF SUBGRADE MATL
368	2.1	1.0	11	AVG LL OF SUBGRADE MATL
372	4.1	1.0	8	SUBGRADE SOIL CONSTANTS
379	4.7	1.0	11	SWELLING CLAY PARAMETER
383	4.2	3.0	8	SPECIFICATION ITEM USED FOR SUBBASE MATERIAL
384	5.0	3.0	8	SUBBASE SOIL TYPE
387	5.0	3.0	10	SUBBASE THICKNESS
402	3.8	1.0	11	SUB-BASE TRIAXIAL CLASS
410	3.8	1.0	11	AVG PI OF SUB-BASE MATL
411	3.8	1.0	11	AVG LL OF SUB-BASE MATL

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
415	4.5	3.0	8	SPECIFICATION ITEM USED FOR BASE
418	3.7	4.0	10	TYPE OF BASE
419	5.0	4.0	10	NUMBER OF LAYERS - BASE
420	3.6	4.0	8	BASE THICKNESS
421	5.0	4.0	10	BASE THICKNESS - TRAFFIC LANE
422	5.0	4.0	10	BASE THICKNESS - SHOULDER
424	2.7	4.0	10	FLEX BASE - DEPTH
427	4.7	4.0	11	TYPE OF STABILIZATION - BASE
435	3.3	4.0	8	BASE MATERIAL
437	3.9	4.0	10	TYPE OF BASE MATERIAL - SHOULDER
457	3.7	1.0	11	BASE TRIAXIAL CLASS
459	3.8	1.0	11	BASE MODULUS
464	4.0	1.0	11	AVG PI OF BASE MATL
465	4.0	1.0	11	AVG LL OF BASE MATL
474	2.6	3.0	9	TYPE OF MEMBRANE BETWEEN BASE MATL AND PAVEMENT
475	3.1	3.0	11	SPECIFICATION ITEM USED FOR SURFACE TREATMENT
477	5.0	3.0	10	TYPE OF SURFACING
478	5.0	3.0	11	TYPE OF ACP SURFACE COURSE

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
480	5.0	4.0	10	SURFACE COURSE THICKNESS
488	4.6	3.0	10	SPECIFICATION ITEM USED FOR CONCRETE PAVEMENT
489	5.0	1.0	10	CONCRETE PAVEMENT DESIGN STANDARD (CPJR,CPCR,ETC)
494	2.6	1.0	13	LOCATIONS OF CONC PVMT LESS THAN PLAN THICKNESS
496	1.8	1.0	13	FORMED OR FORMLESS PLACEMENT - CONCRETE PVMT
500	5.0	1.0	11	CONCRETE PVT DESIGN MIX
501	3.6	2.0	11	TYPE OF CEMENT - CONCRETE PAVEMENT
502	2.2	3.0	11	BRAND OF CEMENT - CONCRETE PAVEMENT
504	3.4	3.0	11	TYPE OF CONCRETE MIX ADDITIVES
506	2.4	3.0	11	BRAND OF AIR ENTRAINING AGENT USED IN CONCRETE PVMT
509	4.0	3.0	11	PERCENT OF AIR ENTRAINING USED IN CONCRETE PAVEMENT
514	4.1	2.0	11	TYPE OF MINERAL FILLER
515	.9	2.0	11	SOURCE OF MINERAL FILLER
516	5.0	1.0	11	TYPE OF BOND BREAKER
518	2.3	2.0	11	SOURCE OF WATER USED IN CONCRETE PAVEMENT
522	3.6	2.0	11	AVERAGE CAF - CONCRETE PAVEMENT
524	4.0	1.0	11	L.A. ABRASION FOR COARSE AGGREGATE
526	2.7	2.0	11	SIEVE ANALYSIS OF AGGREGATE FOR CONC PVT

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
531	4.2	1.0	11	CONCRETE CEMENT FACTOR
532	3.7	1.0	11	CONCRETE WATER FACTOR
535	5.0	1.0	11	CONCRETE TEMPERATURE
537	3.3	2.0	11	MIXING TIME
539	2.9	2.0	11	CURING METHOD - CONCRETE PAVEMENT
540	2.5	2.0	11	CURING COMPOUND
543	1.6	1.0	13	LOCATIONS OF CONC PVMT OPENED TO EMERGENCY TRAFFIC
545	4.3	2.0	11	TYPE VIBRATION
546	4.2	2.0	11	AVERAGE SLUMP USED IN CONC PVT
547	.7	2.0	11	AVG SPECIFIC SURF AREA OF CEMENT - CONCRETE PAVEMENT
553	.8	1.0	11	CONCRETE TEST PROCEDURES
554	3.5	1.0	11	CONCRETE FLEXURAL STRENGTH
560	5.0	1.0	11	PAVEMENT MODULUS
562	4.3	1.0	11	AVERAGE TEXTURE DEPTH
566	3.4	3.0	10	TYPE OF EXPANSION JOINT - CONCRETE PAVEMENT
567	3.4	3.0	10	EXPANSION JOINT SPACING - CONCRETE PAVEMENT
568	2.8	3.0	13	TYPE OF MATERIAL USED IN EXPANSION JOINTS
569	3.5	2.0	10	TYPE OF CONTRACTION JOINT - CONCRETE PAVEMENT

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
570	3.3	2.0	10	CONTRACTION JOINT SPACING - CONCRETE PAVEMENT
571	3.0	2.0	13	TYPE OF MATERIAL USED IN CONTRACTION JOINTS
572	3.8	2.0	10	TYPE OF LONGITUDINAL JOINT - CONCRETE PAVEMENT
574	3.8	2.0	13	TYPE OF MATERIAL USED IN LONGITUDINAL JOINTS
578	4.4	3.0	11	DEPTH OF SAWED JOINT
579	2.8	3.0	11	WIDTH OF SAWED JOINT
580	4.4	3.0	11	TIME OF SAWING SAWED JOINT
582	3.3	3.0	8	CLASS OF JOINT SEALING MATL - CONC PVMT
583	4.5	3.0	9	TYPE OF LONGITUDINAL JOINT SEALER - CONCRETE PAVEMENT
584	4.5	3.0	9	TYPE OF TRANSVERSE JOINT SEALER - CONCRETE PAVEMENT
586	2.4	3.0	10	TYPE OF REINFORCEMENT
588	5.0	3.0	10	PERCENT OF REINFORCEMENT
591	3.9	1.0	10	TYPE OF STEEL
624	2.3	2.0	11	STEEL PLACEMENT (HAND OR MACHINE)
625	5.0	3.0	11	SPECIFICATION ITEM USED FOR ACP
630	.9	3.0	11	TYPE OF ACP MIXING PLANT (WT BATCHING OR CONTINUOUS)
633	5.0	2.0	4	STABILITY OF HMAC
637	4.1	3.0	10	ASPHALT TYPE

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
638	2.6	3.0	11	TYPE OF ASPHALT USED FOR TACK COAT
639	1.9	3.0	11	TYPE OF ASPHALT MATL USED FOR PRIME COAT
640	5.0	3.0	11	TYPE OF ASPHALT USED FOR SURFACE TREATMENT
644	4.9	2.0	13	PERCENT ASPHALT (BY WEIGHT OF AGGREGATE)
649	5.0	3.0	11	AGGREGATE TYPE
650	4.0	3.0	11	TYPE OF COARSE AGGREGATE
651	4.0	3.0	11	TYPE OF INTERMEDIATE AGGREGATE
652	4.0	3.0	11	TYPE OF FINE AGGREGATE
654	5.0	3.0	11	AGGREGATE GRADE
660	4.2	2.0	11	SKID FACTOR OF SURFACE AGGREGATES
665	3.1	3.0	11	RATE OF TACK COAT ASPHALT USED (GAL/S.Y.)
666	2.5	3.0	11	RATE USED FOR PRIME COAT ASPHALT (GAL/S.Y.)
667	5.0	3.0	11	RATE OF ASPHALT USED FOR SURFACE TREATMENT (GAL/S.Y.)
669	5.0	3.0	11	RATE OF AGGREGATE USED FOR SURFACE TREATMENT
671	5.0	3.0	8	TYPE OF COMPACTION (ACP)
672	5.0	1.0	11	ASPHALT MIX DENSITY
701	5.0	3.0	11	TYPE OF ACP LEVEL-UP COURSE
707	5.0	4.0	9	ROUTINE MAINTAINANCE OPERATIONS

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
710	5.0	4.0	9	PREVENTIVE MAINTENANCE MEASURES
713	3.3	3.0	9	TYPE OF REPAIRS REQUIRED
716	5.0	3.0	12	TYPE OF EACH MAINTENANCE EVENT
717	5.0	2.0	11	DATE OF EACH SURFACE MAINTENANCE
731	4.5	4.0	12	DATE OF LAST MAJOR REHABILITATION
732	5.0	4.0	12	TYPE OF LAST MAJOR REHABILITATION
735	2.3	4.0	9	NUMBER OF SEAL COATS
736	3.3	4.0	10	DATE OF SEAL COATS
737	2.7	4.0	9	DATE OF LAST SEAL COAT
744	2.7	3.0	11	AGGREGATE TYPE - SEALS, PRIMES, CURING
747	3.5	3.0	11	ASPHALT TYPE - SEALS,PRIMES,CURING
755	4.0	4.0	13	DATE OF OVERLAY CONSTRUCTION
757	5.0	3.0	12	OVERLAY TYPE
763	4.1	3.0	10	PLANNED FUTURE OVERLAYS - TIME,NUMBER,TYPE
773	2.9	3.0	9	TYPE OF MATERIAL TO REPAIR SPALLED JOINTS
791	4.3	2.0	10	INITIAL COST OF CONSTRUCTION
809	2.5	3.0	13	COST OF SUBGRADE PREPARATION/LANE MILE
813	2.5	3.0	13	COST OF SUB-BASE/LANE MILE -TRAFFIC LANE

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
814	2.5	3.0	13	COST OF SUB-BASE/LANE MILE - SHOULDER
817	2.4	3.0	13	COST OF BASE/LANE MILE -TRAFFIC LANE
818	2.5	3.0	13	COST OF BASE/LANE MILE - SHOULDER
826	2.5	3.0	13	COST OF SURFACING/LANE MILE -TRAFFIC LANE
827	2.5	3.0	13	COST OF SURFACING/LANE MILE - SHOULDER
854	4.8	2.0	12	MAINTENANCE COST PER LANE MI. PER YEAR
856	5.0	2.0	9	ANNUAL MAINT COST OF TRAFFIC LANES SUBGRADE/LANE MILE
857	5.0	2.0	9	ANNUAL MAINT COST OF SHOULDER SUBGRADE/LANE MILE
858	5.0	2.0	9	ANNUAL MAINT COST OF TRAFFIC LANES SUB-BASE/LANE MILE
859	5.0	2.0	9	ANNUAL MAINT COST OF SHOULDER SUB-BASE/LANE MILE
860	5.0	2.0	9	ANNUAL MAINT COST OF TRAFFIC LANES BASE/LANE MILE
861	5.0	2.0	9	ANNUAL MAINT COST OF SHOULDER BASE/LANE MILE
862	5.0	2.0	9	ANNUAL MAINT COST OF TRAFFIC LANES SURFACE/LANE MILE
863	5.0	2.0	9	ANNUAL MAINT COST OF SHOULDER SURFACE/LANE MILE
865	3.3	2.0	9	ANNUAL MAINT COST OF MEDIAN/MILE
866	3.8	2.0	9	ANNUAL MAINT COST OF MEDIAN BARRIER/MILE
876	2.5	2.0	11	CONSTRUCTION METHOD
882	2.4	2.0	11	CONSTRUCTION EQUIPMENT USED

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
894	3.9	1.0	11	FREQUENCY OF EQUIPMENT BREAKDOWNS
902	3.7	3.0	11	IDENTIFICATION OF SUPPLIER - ASPHALT
905	2.5	3.0	11	IDENTIFICATION OF SUPPLIER - STABILIZATION AGENT
908	3.5	3.0	11	IDENTIFICATION OF SUPPLIER - AGGREGATE (COARSE)
909	3.5	3.0	11	IDENTIFICATION OF SUPPLIER - AGGREGATE (INTERMEDIATE)
910	3.5	3.0	11	IDENTIFICATION OF SUPPLIER - AGGREGATE (FINE)
911	2.2	3.0	11	IDENTIFICATION OF SUPPLIER - PRIME COAT MATL
915	4.7	.3	8	SPECIAL DESIGN PROBLEMS
916	4.6	1.0	8	SPECIAL CONSTRUCTION METHODS USED
920	4.6	1.0	12	SPECIAL COMMENTS
922	5.0	3.0	11	TEMPERATURE DURING PAVING
933	2.5	2.0	16	ANNUAL AVERAGE TEMPERATURE
944	5.0	2.0	16	MINIMUM TEMPERATURE
959	3.3	2.0	16	AVERAGE NUMBER OF FREEZE-THAW CYCLES PER YEAR
964	3.2	2.0	16	ANNUAL AVERAGE RAINFALL
966	3.2	2.0	16	MONTHLY AVERAGE RAINFALL
977	2.7	2.0	11	AVERAGE HUMIDITY
992	4.7	1.0	5	PREDICTED TRAFFIC LOADS (18K EQUIV)

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
1012	4.2	1.0	12	DESIGN LOAD
1013	4.2	1.0	12	TRAFFIC LOAD
1015	5.0	1.0	14	MAXIMUM TOTAL LOAD
1022	5.0	1.0	14	NUMBER OF SUPER HEAVY WHEEL LOADS DAILY
1026	5.0	1.0	12	AVERAGE WEIGHT OF OVERLOAD
1040	4.0	1.0	5	ESTIMATED AVERAGE ANNUAL ADT
1042	5.0	1.0	5	CURRENT ADT
1043	3.9	1.0	5	YEARLY ADT
1051	5.0	1.0	5	PERCENT TRUCKS IN AADT
1058	4.8	1.0	5	LANE TRAFFIC DISTRIBUTION (PERCENT)
1062	3.6	4.0	12	SPEED LIMIT
1080	5.0	1.0	8	TYPE OF DETERIORATION (OBSERVED EVERY 6 MONTHS)
1082	5.8	1.0	12	DISTRICT MAINTENANCE RATING/ANNUALLY
1091	4.5	1.0	11	ANNUAL RIDING QUALITY OF PAVEMENT (MAYS ROAD METER)
1096	3.4	1.0	11	DATE OF SERVICEABILITY INDEX RATING
1101	3.5	1.0	11	INITIAL SERVICEABILITY INDEX
1102	2.9	1.0	11	PRESENT SERVICEABILITY INDEX
1111	5.0	1.0	14	ANNUAL SKID RESISTANCE PROFILE

ITEM NUMBER	IMPORTANCE RATING (0.0 TO 5.0)	EXPERTISE RATING (0.3 TO 5.0)	WHO SUPPLIES (CODE)	DATA ITEM DESCRIPTOR (60 LETTERS AND EMBEDDED BLANKS)
1137	5.0	1.0	11	DYNAFLECT DEFLECTION (SURFACE)
1138	3.8	1.0	14	DEFLECTION - YEAR
1148	5.0	1.0	9	CRACK RATING
1169	5.0	3.0	9	PERCENT LANE MI OF PVMT WITH CONTRACTION CRACKS
1170	5.0	3.0	9	PERCENT LANE MI OF PVMT WITH REFLECTION CRACKS
1242	4.9	1.0	11	EXISTING MOISTURE CONTENT OF SUBGRADE -SAMPLE- EA 6 MOS

APPENDIX D

COGNITIVE STYLE AND ATTITUDE SCALES

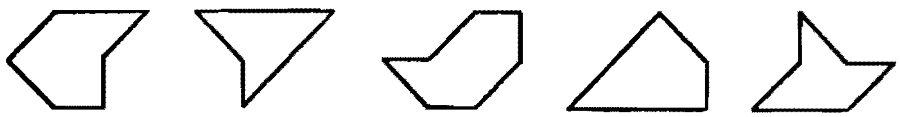
Name: ____

HIDDEN FIGURES TEST — Cf-1

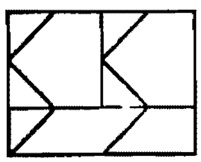
This is a test of your ability to tell which one of five simple figures can be found in a more complex pattern. At the top of each page in this test are five simple figures lettered A, B, C, D, and E. Beneath each row of figures is a page of patterns. Each pattern has a row of letters beneath it. Indicate your answer by putting an X through the letter of the figure which you find in the pattern.

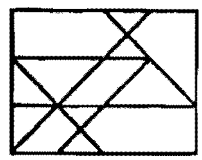
NOTE: There is only one of these figures in each pattern, and this figure will always be right side up and exactly the same size as one of the five lettered figures.

Now try these 2 examples.

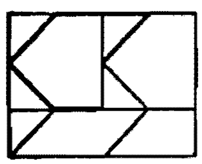


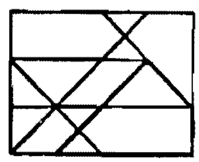
A B C D E

I 
A B C D E

II 
A B C D E

The figures below show how the figures are included in the problems. Figure A is in the first problem and figure D in the second.

I 
X B C D E

II 
A B C X E

Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have 10 minutes for each of the two parts of this test. Each part has 2 pages. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Developed under NIMH Contract M-4186

Name ____________________

Date ____________________

PFDS OPINION SURVEY

INSTRUCTIONS

The purpose of this questionnaire is to obtain your opinion of the Pavement Feedback Data System (PFDS) that is presently being considered for implementation. Do not begin the questionnaire until you have thoroughly read the instructions below.

You are asked to read carefully each of the 25 statements that follow and to circle quickly the letter or letter combination to the left of the statement which best expresses your feeling about the statement. The following letters are abbreviations for the phrases given immediately above them:

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
SD	D	U	A	SA

Circling the A in the letters to the left of the statement would indicate that you agree with the statement.

PART I

This part of the questionnaire is concerned with how you feel about each statement as it applies to the situation after PFDS is operational. For example, statement 1

"It will be easier to perform my job well."

implies

It will be easier to perform my job well after PFDS is in use.

Whenever possible, let your own personal experience determine your answer. Do not spend much time on any one statement. WORK RAPIDLY and be sure to answer every statement.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Name ______________________

1.	SD	D	U	A	SA	It will be easier to perform my job well.
2.	SD	D	U	A	SA	The sooner PFDS is in use the better.
3.	SD	D	U	A	SA	My counterparts in other divisions and districts are generally resistant to changes of this type.
4.	SD	D	U	A	SA	I will be able to improve my performance.
5.	SD	D	U	A	SA	My job will be more satisfying.
6.	SD	D	U	A	SA	I will have to spend more time looking for information.
7.	SD	D	U	A	SA	Others will be more aware of what I am doing.
8.	SD	D	U	A	SA	The information that will be contained in PFDS is not needed now.
9.	SD	D	U	A	SA	I will be able to see better the results of my efforts.
10.	SD	D	U	A	SA	I will have more control over my job.
11.	SD	D	U	A	SA	The PFDS project is technically sound.
12.	SD	D	U	A	SA	Texas Highway Department (THD) goals will become more obscure.
13.	SD	D	U	A	SA	The accuracy of my work will improve as the result of using PFDS.
14.	SD	D	U	A	SA	The accuracy of the information I receive will not be improved by the use of PFDS.
15.	SD	D	U	A	SA	PFDS should be put into use as soon as practical.
16.	SD	D	U	A	SA	PFDS is not important to me.
17.	SD	D	U	A	SA	The people implementing PFDS do not realize how complex the pavement problem is.
18.	SD	D	U	A	SA	The information I will receive from PFDS will make my job harder.
19.	SD	D	U	A	SA	The aims of my counterparts in other divisions and districts will not be as easily achieved.
20.	SD	D	U	A	SA	My goals and the THD goals will be more similar than they are now.

Name ______________________

PART II

This part of the survey is concerned with obtaining your opinion of the effect that your participation in the design of PFDS will have on the system.

21.	SD	D	U	A	SA	Those implementing PFDS respect my opinions.
22.	SD	D	U	A	SA	My participation in the PFDS design process will help to provide me with training that will be valuable in using the system when it is operational.
23.	SD	D	U	A	SA	My participation in the PFDS design process will not be helpful to the system.
24.	SD	D	U	A	SA	I will not enjoy working on the PFDS data base design.
25.	SD	D	U	A	SA	I am not happy that my opinions are being incorporated in the design of the PFDS system.

APPENDIX E

PARTICIPANT DATA

PFDS EXPERIMENTAL DATA

INDIV NO.	HFT	ITEMS	ATT (PRE)	ATT (POST)	RANK HFT	RANK ATT
10	.25	4	79	74	12	202
11	6.25	7	61	59	53	70
12	4.00	13	66	72	35	104
13	-.25	14	66	63	8	114
14	7.50	15	67	70	71	123
15	-1.75	16	62	57	2	81
16	4.25	20	68	58	36	131
17	6.00	21	67	72	52	119
18	7.75	29	82	77	73	209
19	6.50	32	67	67	57	121
20	3.00	9	64	70	28	95
21	7.00	9	69	65	68	144
22	7.00	9	70	71	67	153
23	1.75	10	61	77	20	69
24	0.00	12	65	69	11	100
25	0.00	15	59	71	10	63
26	6.00	17	70	77	51	158
27	6.50	23	61	65	56	76
28	2.50	30	63	66	25	87
29	6.50	37	70	63	55	154
30	1.00	7	66	68	16	116
31	2.00	7	67	68	23	117
32	6.75	10	74	73	60	181
33	3.00	10	62	71	27	79

INDIV NO.	HFT	ITEMS	ATT (PRE)	ATT (POST)	RANK HFT	RANK ATT
34	1.25	10	67	73	17	128
35	7.00	15	62	68	66	82
36	4.50	16	82	73	39	207
37	5.75	27	68	73	48	140
38	5.75	31	69	71	47	145
39	4.75	38	83	74	42	211
40	-.75	8	58	59	5	53
41	6.75	10	68	70	59	141
42	8.00	10	72	72	78	171
43	-1.25	14	59	65	3	64
44	4.00	14	59	69	34	61
45	3.75	15	68	63	33	135
46	6.00	16	58	63	50	55
47	3.75	20	66	72	32	106
48	7.00	29	65	80	65	98
49	5.00	35	72	64	44	170
50	11.75	5	65	62	130	97
51	11.00	14	67	57	117	125
52	8.75	15	64	76	86	91
53	8.25	19	66	79	79	107
54	11.25	21	70	72	120	152
55	13.00	24	77	78	145	197
56	11.50	26	66	67	124	112
57	9.25	37	70	73	94	160
58	9.75	45	66	69	99	108

INDIV NO.	HFT	ITEMS	ATT (PRE)	ATT (POST)	RANK HFT	RANK ATT
59	11.75	48	68	63	129	133
60	8.00	10	76	84	77	192
61	8.00	12	76	74	76	191
62	13.00	15	62	54	144	80
63	12.75	18	68	68	139	138
64	10.00	22	66	60	104	115
65	12.75	25	79	80	138	200
66	8.75	27	70	67	85	157
67	11.75	32	82	80	128	208
68	11.50	45	64	50	123	90
69	10.50	49	64	62	105	89
70	11.00	10	67	73	116	120
71	9.00	11	73	71	93	178
72	11.00	12	61	74	115	74
73	8.00	17	72	71	75	172
74	10.75	24	65	59	106	99
75	13.00	26	77	66	143	196
76	11.00	29	58	65	114	54
77	9.00	33	67	65	92	122
78	11.50	45	71	75	122	168
79	11.00	49	84	74	113	212
80	8.50	10	67	58	81	126
81	13.00	14	66	73	142	113
82	12.75	15	60	69	137	66
83	10.00	20	66	65	103	110

INDIV NO.	HFT	ITEMS	ATT (PRE)	ATT (POST)	RANK HFT	RANK ATT
84	10.00	24	74	73	102	185
85	8.00	26	79	70	74	201
86	13.50	29	73	70	147	177
87	9.00	30	60	57	91	65
88	9.00	36	64	71	90	96
89	12.75	50	83	75	136	210
90	19.00	16	63	65	192	85
91	16.00	20	72	70	170	175
92	17.00	22	71	66	178	165
93	19.00	25	61	58	191	68
94	19.00	26	75	63	190	186
95	18.00	29	69	71	182	150
96	14.00	34	74	74	157	184
97	18.75	47	62	60	184	78
98	19.00	62	68	63	189	136
99	14.00	63	69	69	156	147
100	21.00	13	74	68	194	183
101	16.25	15	63	67	172	84
102	14.00	19	72	55	155	173
103	15.00	22	76	75	163	190
104	23.00	26	68	66	198	134
105	14.00	29	63	55	154	86
106	16.75	46	69	74	174	149
107	18.00	50	70	65	181	161
108	16.75	52	61	56	173	72

INDIV NO.	HFT	ITEMS	ATT (PRE)	ATT (POST)	RANK HFT	RANK ATT
109	21.00	69	65	69	193	102
110	16.00	21	73	66	169	176
111	15.00	21	72	60	162	174
112	15.75	23	73	71	167	180
113	14.75	25	58	60	160	56
114	13.75	29	59	85	151	59
115	15.75	31	67	62	166	129
116	26.00	32	64	71	200	92
117	17.00	43	72	69	177	169
118	13.50	51	75	67	146	187
119	24.00	66	67	64	199	124
120	16.00	12	69	62	168	146
121	17.00	17	66	70	176	105
122	15.00	18	74	73	161	182
123	19.00	23	71	65	188	163
124	19.00	24	66	-0	187	103
125	18.00	25	59	63	180	62
126	17.75	27	59	69	179	60
127	13.75	31	81	74	150	206
128	14.25	36	63	68	158	83
129	22.50	130	64	70	196	94
130	12.00	21	16	63	134	1
131	9.00	40	53	39	89	29
132	10.00	14	53	65	101	27
133	1.50	22	54	73	18	33

INDIV NO.	HFT	ITEMS	ATT (PRE)	ATT (POST)	RANK HFT	RANK ATT
134	7.00	16	55	69	64	34
135	11.75	52	55	57	127	39
136	-.25	25	55	62	7	38
137	7.00	20	56	66	63	45
138	11.00	17	56	58	112	43
139	8.50	15	57	66	80	51
140	6.50	32	41	62	54	7
141	3.75	10	47	50	31	12
142	11.25	15	47	72	119	10
143	9.75	60	50	69	98	16
144	.75	23	50	47	15	18
145	9.00	30	52	32	88	21
146	17.00	29	53	62	175	26
147	0.00	5	55	56	9	35
148	9.00	12	56	63	87	41
149	13.00	24	57	64	141	49
150	14.00	30	46	70	153	9
151	-3.00	8	47	34	1	11
152	9.75	20	47	-0	97	13
153	6.75	22	50	47	58	15
154	22.00	13	51	57	195	19
155	7.50	13	52	-0	70	22
156	2.00	37	52	71	22	24
157	9.50	62	53	57	95	30
158	4.50	9	55	58	38	36

INDIV NO.	HFT	ITEMS	ATT (PRE)	ATT (POST)	RANK HFT	RANK ATT
159	4.75	25	55	60	41	37
160	11.75	16	36	36	126	4
161	1.75	50	44	65	19	8
162	11.00	11	49	62	111	14
163	13.75	21	52	65	149	25
164	11.00	48	52	-0	110	23
165	3.75	8	53	65	30	28
166	12.00	33	54	58	133	32
167	4.75	15	56	68	40	42
168	.75	15	56	75	14	44
169	5.25	22	57	60	45	50
170	12.75	20	36	57	135	3
171	2.00	32	56	-0	21	40
172	8.75	108	57	56	84	48
173	8.75	73	61	67	83	75
174	7.75	21	62	59	72	77
175	14.75	11	67	68	159	118
176	14.00	7	69	69	152	142
177	12.00	10	70	73	132	155
178	11.00	28	78	71	109	198
179	7.00	50	79	-0	62	203
180	3.75	10	38	42	29	5
181	.75	13	57	61	13	52
182	22.75	9	59	48	197	58
183	9.75	4	60	66	96	67

INDIV NO.	HFT	ITEMS	ATT (PRE)	ATT (POST)	RANK HFT	RANK ATT
184	11.25	84	64	37	118	88
185	11.75	109	70	69	125	151
186	13.75	8	70	72	148	159
187	7.00	48	71	74	61	167
188	5.75	47	71	65	46	162
189	10.00	59	80	83	100	205
190	2.25	4	51	47	24	20
191	11.00	8	69	71	108	143
192	15.75	8	61	60	165	73
193	6.00	20	40	60	49	6
194	19.00	29	61	4	186	71
195	8.75	47	86	92	82	213
196	13.00	52	68	70	140	139
197	11.50	55	67	72	121	127
198	-.50	70	76	70	6	195
199	11.00	90	66	68	107	111
200	3.00	7	54	72	26	31
201	15.75	10	70	72	164	156
202	5.00	20	71	67	43	164
203	19.00	7	78	69	185	199
204	18.75	12	75	83	183	188
205	16.25	14	27	22	171	2
206	-.75	20	50	64	4	17
207	4.50	58	73	61	37	179
208	7.50	57	68	-0	69	130

INDIV NO.	HFT	ITEMS	ATT (PRE)	ATT (POST)	RANK HFT	RANK ATT
209	12.00	179	80	87	131	204
210	15.00	14	57	58		47
211	13.75	34	71	73		166
212	6.50	22	66	46		109
213	23.00	23	68	69		132
214	19.75	160	69	71		148
215	12.75	8	64	72		93
216	10.50	22	65	50		101
217	7.75	35	79	77		194
501	17.00		62	61		
502	20.00		69	65		
503	13.75		68	50		
504	14.75		68	61		
505	16.75		76	77		
506	8.00		78	71		
507	13.75		75	66		
508	9.00		65	72		
509	12.00		61	66		
510	11.50		52	46		
511	4.75		53	42		
512	12.25		69	70		
513	.75		57	42		
514	11.75		65	57		
515	7.00		63	65		
516	19.00		79	73		

INDIV NO.	HFT	ITEMS	ATT (PRE)	ATT (POST)	RANK HFT	RANK ATT
517	2.00		54	67		
518	13.50		79	64		
519	12.00		70	68		
520	7.00		66	80		
521	.75		69	56		
522	12.00		65	57		
523	17.00		64	64		
524	17.00		69	69		
525	18.00		59	55		
526	20.00		65	65		
527	.75		66	68		

APPENDIX F

TENTATIVE LIST OF ITEMS FOR PFDS

TENTATIVE LIST OF ITEMS FOR PFDS

In Table F-1 of this Appendix, a working list of items for possible inclusion in PFDS is given along with other information including the importance ratings assigned the items by the participants in the Delphi process. The following is an explanation of the data in Table F-1.

Item	-	arbitrarily assigned identifying numbers for the items
Descriptor	-	descriptions of the items
Avg	-	average of the importance ratings assigned to a given item by the delphi groups that included that item
N	-	number of groups that included the item
Range	-	range of importance ratings assigned to a given item by the different Delphi groups
Groups	-	indication of which delphi groups included a given item. (This is discussed below.)

Under the heading GROUPS, a string of binary numbers are printed corresponding to each item. The binary numbers were actually stored in two words in the computer; thus, since leading zeroes in a computer word are not printed, blanks sometimes appear instead of zeroes.

Each binary number indicates whether one of the Delphi groups included the item under consideration; a 1 indicates that the item was included, and a blank or zero indicates that the item was not included. The groups are numbered from right to left; that is, group 1 is on the far right, and group 21 is on the far left. As discussed in the text of this report, the group numbers have the following significance:

Groups 1- 4: Global
5- 8: Mixed
9-12: Analytical
13-16: Low Attitude
17-20: Control
21: Late

We will now discuss the two remaining steps needed to produce a final data base from the list given here.

First, the redundancies in the list should be eliminated. Table F-2 is a set of redundancies which were reported during the experiment by the delphi participants. This set is presented here without editorial analysis. Random inspection tended to confirm the belief that numerous redundancies do exist. The set is not error-free, however, as evidenced by the very first entry, items 19 and 211, which are definitely unrelated.

Second, a final decision must be made about which items from the list should be included in PFDS. For this purpose, the verbal descriptions of the importance ratings, which are given in Appendix A, will be very helpful. Those descriptions will be repeated here for the convenience of the reader:

5.0 Imperative that item be included
4.0 Highly important
3.0 Moderately important
2.0 Of questionable importance
1.0 Low importance
0.0 Absolutely no importance

While no steadfast method exists for determining the cut-off point, several recommendations are included below. Using the verbal descriptions of the importance ratings given above as a standard, it is suggested that all items having overall importance ratings of 3.0 or more be included, whereas all items with a value of less than 2.0 be excluded from the permanent list. In addition, any item having a RHI value, the highest importance rating given an item by a group, of 4.0 or more should be included, as at least one of the 21 groups considered that item to be highly important. When considering the items remaining, several factors should be examined. It is suggested that attention be paid to both N , an indicator of how many people consider an item to be of some importance, and the range of importance ratings. A larger range of ratings indicates a substantial diversity in feeling towards that item; if there are a few high ratings, inclusion may be warranted, even though the average is low.

Once the items to be included in the final data base list have been decided upon, the next step is to store the corresponding data for the existing pavement network, and add data for new projects as they become available. This data base has the potential to be of great benefit to the engineer in the fields of pavement design, maintenance, and research.

TABLE F-1. COMPUTER SUMMARY OF RESULTS OF ALL 21 GROUPS

PAGE 1

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
6	JOB NUMBER	5.0	2	5.0	5.0	101000000	0
386	TYPE OF SUB-BASE (SHOULDERS)	5.0	1	5.0	5.0	0	10
479	TYPE OF SURFACING - TRUCK LANE	5.0	1	5.0	5.0	0	1
481	SURFACE COURSE THICKNESS - TRUCK LANE	5.0	1	5.0	5.0	0	1
505	IDENTIFICATION OF SUPPLIER - AIR ENTRAINING AGENT	5.0	1	5.0	5.0	1000000	0
507	DOSAGE AIR ENTRAINING AGENT	5.0	1	5.0	5.0	1000000	0
535	CONCRETE TEMPERATURE	5.0	1	5.0	5.0	10	0
560	PAVEMENT MODULUS	5.0	1	5.0	5.0	10	0
671	TYPE OF COMPACTION (ACP)	5.0	1	5.0	5.0	10	0
701	TYPE OF ACP LEVEL-UP COURSE	5.0	1	5.0	5.0	10	0
857	ANNUAL MAINT COST OF SHOULDER SUBGRADE/LANE MILE	5.0	1	5.0	5.0	10	0
859	ANNUAL MAINT COST OF SHOULDER SUB-BASE/LANE MILE	5.0	1	5.0	5.0	10	0
1006	FUTURE 20 YEAR ADT	5.0	1	5.0	5.0	0	100000000
1007	FUTURE 20 YEAR DHV	5.0	1	5.0	5.0	0	100000000
1033	AXLES PER VEHICLE	5.0	1	5.0	5.0	0	100
1050	AXLE GROWTH FACTOR (INDICATES PERCENT TRUCKS)	5.0	1	5.0	5.0	10000	0
1125	DATE OF DYNAFLECT PROFILE	5.0	1	5.0	5.0	0	10
1258	DURABILITY UNDER HEAVY LOADS	5.0	1	5.0	5.0	0	100
1288	TYPE OF SURFACING - TRAFFIC LANE	5.0	1	5.0	5.0	0	10
1289	THICKNESS OF SURFACING - TRAFFIC LANE	5.0	1	5.0	5.0	0	10
1290	TYPE OF SUBBASE - TRAFFIC LANE	5.0	1	5.0	5.0	0	10
1291	DEPTH OF SUBBASE - TRAFFIC LANE	5.0	1	5.0	5.0	0	10
1310	LANE CODE - MAIN, FRONTAGE, CONNECTORS	5.0	1	5.0	5.0	0	10
991	DATE OF EQUIV 18 KIP AXLE DATA	5.0	1	5.0	5.0	1000000000	0
530	SAND EQUIVALENT VALUE	4.9	1	4.9	4.9	0	10000
858	ANNUAL MAINT COST OF TRAFFIC LANES SUB-BASE/LANE MILE	4.9	2	4.8	5.0	10	10
1220	PERCENT LANE MI OF PVMT WITH SLIGHT CORRUGATIONS	4.9	1	4.9	4.9	1000000000	0
1221	PERCENT LANE MI OF PVMT WITH MODERATE CORRUGATIONS	4.9	1	4.9	4.9	1000000000	0
1222	PERCENT LANE MI OF PVMT WITH SEVERE CORRUGATIONS	4.9	1	4.9	4.9	1000000000	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
1216	PERCENT LANE MI OF PVMT WITH SLIGHT FLUSHING	4.9	1	4.9	4.9	1000000000	0
1217	PERCENT LANE MI OF PVMT WITH MODERATE FLUSHING	4.9	1	4.9	4.9	1000000000	0
1218	PERCENT LANE MI OF PVMT WITH SEVERE FLUSHING	4.9	1	4.9	4.9	1000000000	0
1227	PERCENT LANE MI OF PVMT WITH SLIGHT RAVELING	4.9	1	4.9	4.9	1000000000	0
1228	PERCENT LANE MI OF PVMT WITH MODERATE RAVELING	4.9	1	4.9	4.9	1000000000	0
1229	PERCENT LANE MI OF PVMT WITH SEVERE RAVELING	4.9	1	4.9	4.9	1000000000	0
1212	PATCHING -GOOD- PERCENT OF AREA - EA 0.2 MI	4.9	1	4.9	4.9	1000000000	0
1213	PATCHING -FAIR- PERCENT OF AREA - EA 0.2 MI	4.9	1	4.9	4.9	1000000000	0
1214	PATCHING -POOR- PERCENT OF AREA - EA 0.2 MI	4.9	1	4.9	4.9	1000000000	0
301	MATERIAL TYPE OF NATURAL SOIL BELOW SUBGRADE	4.9	1	4.9	4.9	1	0
460	MODULUS OF ELASTICITY OF BASE	4.9	1	4.9	4.9	1	0
609	DISTRIBUTED STEEL SIZE	4.9	1	4.9	4.9	1000000	0
610	DISTRIBUTED STEEL SPACING	4.9	1	4.9	4.9	1000000	0
700	PERCENT WATER ABSORPTION OF AGGREGATE	4.9	1	4.9	4.9	0	100000000
739	PRIMARY REASON FOR SEALING (DEVELOP CODE)	4.9	1	4.9	4.9	10000000	0
1082	DISTRICT MAINTENANCE RATING/ANNUALLY	4.9	2	4.8	5.0	11	0
1203	PUMPING -MINOR- AVG OF PVMT LENGTH EA 0.2 MI	4.9	1	4.9	4.9	1000000000	0
1204	PUMPING -MAJOR- AVG OF PVMT LENGTH EA 0.2 MI	4.9	1	4.9	4.9	1000000000	0
1243	PERCENT LANE MI OF PVMT WITH MAJOR FAILURES	4.9	1	4.9	4.9	100	0
1153	TRANSVERSE CRACKING -SLIGHT- AVG NO PER STA EA .2 MI	4.9	1	4.9	4.9	1000000000	0
1154	TRANSVERSE CRACKING -MODERATE- AVG NO PER STA EA .2 MI	4.9	1	4.9	4.9	1000000000	0
1160	LONGITUDINAL CRACKING - SLIGHT- LIN FT PER STA	4.9	1	4.9	4.9	1000000000	0
1161	LONGITUDINAL CRACKING -MODERATE- LIN FT PER STA	4.9	1	4.9	4.9	1000000000	0
1166	PERCENT LANE MI OF PVMT WITH SLIGHT ALLIGATOR CRACKING	4.9	1	4.9	4.9	1000000000	0
1167	PERCENT LANE MI OF PVMT WITH MODERATE ALLIGATOR CRACKING	4.9	1	4.9	4.9	1000000000	0
1168	PERCENT LANE MI OF PVMT WITH SEVERE ALLIGATOR CRACKING	4.9	1	4.9	4.9	1000000000	0
1188	SPALLING -MINOR-AVG PERCENT OF CRACKED LENGTH EA .2 MI	4.9	1	4.9	4.9	1000000000	0
1189	SPALLING -MAJOR- AVG PERCENT OF CRACKED LENGTH EA .2 MI	4.9	1	4.9	4.9	1000000000	0
1198	PERCENT LANE MI OF PVMT WITH SLIGHT RUTTING	4.9	1	4.9	4.9	1000000000	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
1200	PERCENT LANE MI OF PVMT WITH SEVERE RUTTING	4.9	1	4.9	4.9	1000000000	0
142	PAVEMENT MACRO TEXTURE	4.9	1	4.9	4.9	0	10000000
1119	LOWEST SKID NUMBER (PER CONST JOB)	4.9	1	4.9	4.9	1000000000	0
1121	HIGHEST SKID NUMBER (PER CONST JOB)	4.9	1	4.9	4.9	1000000000	0
1173	FREQUENCY OF IRREGULAR CRACKING	4.9	1	4.9	4.9	0	100000000
1130	DYNAFLECT PROFILE, GEOPHONE 4	4.9	2	4.9	4.9	1000000000	100000000
1066	DATE PERFORMANCE DATA ACQUIRED	4.9	1	4.9	4.9	1000000000	0
1056	FUTURE 20 YEAR DIRECTIONAL DISTRIBUTION FACTOR	4.9	1	4.9	4.9	0	100000000
1219	FREQUENCY OF CORRUGATION	4.9	1	4.9	4.9	0	100000000
1127	DYNAFLECT PROFILE, GEOPHONE 1	4.9	1	4.9	4.9	1000000000	0
1128	DYNAFLECT PROFILE, GEOPHONE 2	4.9	1	4.9	4.9	1000000000	0
1129	DYNAFLECT PROFILE, GEOPHONE 3	4.9	1	4.9	4.9	1000000000	0
1131	DYNAFLECT PROFILE, GEOPHONE 5	4.9	1	4.9	4.9	1000000000	0
552	MEASURED YIELD	4.9	1	4.9	4.9	1000000	0
354	ACTUAL DENSITY (DA) - SUBGRADE	4.9	1	4.9	4.9	10000000	0
1241	FREQUENCY OF SHOVING	4.8	1	4.8	4.8	0	100000000
1247	ANNUAL TOTAL CLAY SWELL - SELECT LOCATIONS	4.8	1	4.8	4.8	0	1000000
198	DESIGN DEPTH OF FLOW SIDE ROAD DITCHES (2 GP)	4.8	1	4.8	4.8	10000000	0
199	OBSERVED DEPTH OF FLOW SIDE ROAD DITCHES	4.8	1	4.8	4.8	10000000	0
461	SOUNDNESS VALUE OF AGGREGATES	4.8	2	4.8	4.9	1000000	100000000
1159	PERCENT OF PVMT WITH LONGITUDINAL CRACKS - AT OVERLAY	4.8	1	4.8	4.8	10000000	0
320	TYPE OF SOIL - BORROW MATERIAL	4.8	1	4.8	4.8	10000000	0
9	MAINTENANCE SECTION	4.8	1	4.8	4.8	10	0
994	INITIAL 18 KIP EQUIV AXLES PER DAY	4.8	1	4.8	4.8	10000000	0
1064	AVERAGE TRUCK SPEED	4.8	1	4.8	4.8	100000	0
225	AGGREGATE TYPE - LAYER	4.8	2	4.5	5.0	0	101
389	DEPTH OF SUBBASE - SHOULDER	4.8	2	4.5	5.0	1000000000	10
1205	PUNCH OUTS -MINOR- NUM IN .2 MI 1 TO 3 FT IN SIZE	4.7	1	4.7	4.7	1000000000	0
1206	PUNCH OUTS -MINOR- NUM IN .2 MI 4 TO 9 FT IN SIZE	4.7	1	4.7	4.7	1000000000	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
1207	PUNCH OUTS -MINOR- NUM IN .2 MI GT 10 FT IN SIZE	4.7	1	4.7	4.7	1000000000	0
1208	PUNCH OUTS -MAJOR- NUM IN .2 MI 1 TO 3 FT IN SIZE	4.7	1	4.7	4.7	1000000000	0
1209	PUNCH OUTS -MAJOR- NUM IN .2 MI 4 TO 9 FT IN SIZE	4.7	1	4.7	4.7	1000000000	0
1210	PUNCH OUTS -MAJOR- NUM IN .2 MI GT 10 FT IN SIZE	4.7	1	4.7	4.7	1000000000	0
719	TYPE OF SPECIAL MAINT PROJECTS UNDERTAKEN	4.7	2	4.5	4.9	10000000	1
623	DEPTH OF CONCRETE COVER	4.7	1	4.7	4.7	1000000000	0
267	FATIGUE CHARACTERISTICS OF EACH LAYER	4.7	1	4.7	4.7	0	100000
534	PASTE FACTOR	4.7	1	4.7	4.7	1000000	0
893	TYPE OF SPREADER	4.7	1	4.7	4.7	1000000	0
1045	ADT AFTER EACH OVERLAY	4.7	1	4.7	4.7	10000000	0
1079	DESCRIPTION OF ANY UNUSUAL FAILURES	4.7	1	4.7	4.7	100	0
1081	DISTRICT DESIGN RATING/ANNUALLY	4.7	1	4.7	4.7	1	0
1155	TRANSVERSE CRACKING -SEVERE- AVG NO PER STA EA .2 MI	4.7	2	4.5	4.9	11000000000	0
1162	LONGITUDINAL CRACKING -SEVERE- LIN FT PER STA	4.7	2	4.5	4.9	11000000000	0
1309	PAVEMENT DESIGN	4.7	1	4.7	4.7	100000000	0
558	CONCRETE DESIGN STRENGTH (MODULUS OF RUPTURE)	4.7	4	4.1	5.0	1000000	100110000
995	18 KIP EQUIV AXLES PER DAY AFTER EACH OVERLAY	4.7	1	4.7	4.7	10000000	0
1134	DYNAFLECT DEFLECTION (SUBGRADE)	4.7	3	4.0	5.0	100000	110
361	SUBGRADE TRIAXIAL CLASS/TREATED	4.7	2	4.3	5.0	10000010	0
204	ACCESSABILITY OF SURFACE WATER TO BASE	4.7	1	4.7	4.7	10	0
221	PERCENT OF STABILIZATION FOR EACH LAYER	4.7	2	4.5	4.8	100001	0
583	TYPE OF LONGITUDINAL JOINT SEALER - CONCRETE PAVEMENT	4.7	2	4.5	4.8	10000010	0
1199	PERCENT LANE MI OF PVMT WITH MODERATE RUTTING	4.6	2	4.4	4.9	1000000001	0
490	TYPE OF CONCRETE PAVEMENT	4.6	7	3.4	5.0	1111001001	100000000
448	DENSITY - STABILIZED BASE	4.6	1	4.6	4.6	10000000	0
239	PERCENT BINDER IN EACH LAYER IN PLACE	4.6	3	4.6	4.7	1000000	110000
589	PERCENT LONGITUDINAL STEEL IN EACH LAYER	4.6	3	4.4	5.0	1001010000	0
161	FREQUENCY OF GRADE POINTS	4.6	1	4.6	4.6	100000	0
238	TYPE OF ACMIX - LAYER	4.6	1	4.6	4.6	1	0

(Continued)

TABLE F-1. (Continued)

PAGE 5

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
488	SPECIFICATION ITEM USED FOR CONCRETE PAVEMENT	4.6	1	4.6	4.6	10	0
550	DESIGN DENSITY OF CONCRETE (WT/CU.FT.)	4.6	1	4.6	4.6	1000000	0
920	SPECIAL COMMENTS	4.6	1	4.6	4.6	10	0
1[illegible]39	DESIGN YEAR ADT	4.6	3	3.7	5.0	11000001000	0
634	TEMPERATURE OF MIX AT LAY DOWN	4.6	2	4.4	4.7	0	100010000
775	LOCATION WHERE EMULSIFIED ASPHALT USED IN MAINT.	4.6	1	4.6	4.6	0	1
516	TYPE OF BOND BREAKER	4.5	2	4.1	5.0	101000000000	
1[illegible]26	AVERAGE WEIGHT OF OVERLOAD	4.5	2	4.1	5.0	1000010	0
1[illegible]22	NUMBER OF SUPER HEAVY WHEEL LOADS DAILY	4.5	2	4.1	5.0	10	10000
135	PAVEMENT THICKNESS OVERALL	4.5	16	3.6	5.0	1111111111111101100	
1248	CONTINUOUS INVENTORY OF SWELLING CLAY AREAS	4.5	1	4.5	4.5	0	1000000
997	18 KIP EQUIV. (DISTRICT ESTIMATE)	4.5	1	4.5	4.5	10000000	0
304	DEPTH OF FOUNDATION COURSE	4.5	1	4.5	4.5	1000000000	0
180	SUBSOIL CONDITIONS	4.5	4	4.0	5.0	11000	10100000
392	TYPE OF STABILIZATION - SUBBASE	4.5	3	4.3	4.8	1000000000	1010000
1[illegible]85	SHOULDER RATING SCORE - PROJECT 151	4.5	1	4.5	4.5	1000	0
576	TRANSVERSE JOINT SPACING	4.5	1	4.5	4.5	100	0
38	ANTICIPATED FUTURE POPULATION OF AREA (D-10)	4.5	1	4.5	4.5	10000000	0
207	TYPE OF CONSTRUCTION CONTROL EACH LAYER	4.5	1	4.5	4.5	10000000000	0
305	FOUNDATION COURSE DEPTH - SHOULDER	4.5	1	4.5	4.5	1000000000	0
394	PERCENT CONTENT OF STABILIZATION - SUBBASE	4.5	1	4.5	4.5	1000000000	0
472	SOIL CONSTANTS - BASE	4.5	1	4.5	4.5	01000000000	
478	TYPE OF ACP SURFACE COURSE	4.5	2	4.0	5.0	1000000010	0
584	TYPE OF TRANSVERSE JOINT SEALER - CONCRETE PAVEMENT	4.5	1	4.5	4.5	10	0
93	ARMOR JOINTS (BRIDGE ABUTMENTS) - MATERIAL TYPE	4.5	1	4.5	4.5	0	1
672	ASPHALT MIX DENSITY	4.5	2	4.0	5.0	110	0
863	ANNUAL MAINT COST OF SHOULDER SURFACE/LANE MILE	4.5	2	4.0	5.0	1010	0
15	LOCATION OF TEMPORARY RIGHT OF WAY USE AGREEMENTS	4.5	1	4.5	4.5	0	1
1[illegible]78	TYPE OF SURFACE FAILURE FIRST OBSERVED	4.5	2	4.0	5.0	10001000000	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE BLW	RANGE BHI	GROUPS	
1104	SERVICEABILITY INDEX AT DECISION TO OVERLAY	4.5	1	4.5	4.5	10000000	0
1105	SERVICEABILITY INDEX AFTER EACH OVERLAY	4.5	1	4.5	4.5	10000000	0
51	LOCATION OF TRAFFIC SIGNS	4.5	1	4.5	4.5	0	1
1164	SPACING OF LONGITUDINAL CRACKS	4.5	1	4.5	4.5	1	0
1	DISTRICT NUMBER	4.5	4	3.9	4.8	1011000	10000
491	CONCRETE PAVEMENT THICKNESS	4.5	14	3.8	5.0	11111101001	101101101
125	DATE WIDENING COMPLETED	4.5	1	4.5	4.5	10000000	0
11	ENDING MILEPOINT	4.5	3	3.7	5.0	101001000	0
3	SECTION	4.5	6	3.9	5.0	101011010	10000
489	CONCRETE PAVEMENT DESIGN STANDARD (CPJR,CPCR,ETC)	4.5	5	3.3	5.0	1010010	101
1245	ANNUAL SWELLING CLAY RATE - SELECT LOCATIONS	4.5	1	4.5	4.5	0	1000000
417	CLASSIFICATION OF BASE	4.5	3	4.2	4.8	1000000001001000000	
275	MAX PI OF EACH LAYER	4.4	2	4.0	4.9	10000001000000000	
555	AVERAGE BEAM BREAKS	4.4	3	4.0	4.8	100	1100000
421	BASE THICKNESS - TRAFFIC LANE	4.4	4	3.6	5.0	101000010	10
1017	DATHWLD (DESIGN AVG TEN HEAVIEST WHEEL LOADS DAILY)	4.4	3	3.7	4.9	1	100010000
454	COMPRESSIVE STRENGTH (UNCONFINED) - CEMENT STAB BASE	4.4	2	4.1	4.8	10000001	0
1176	CRACKING (SQ FT/1000 SQ FT) AT DECISION TO OVERLAY	4.4	1	4.4	4.4	10000000	0
1156	SPACING OF TRANSVERSE CRACKS	4.4	2	4.4	4.5	11000000000	
915	SPECIAL DESIGN PROBLEMS	4.4	2	4.2	4.7	10	1000000
573	LONGITUDINAL JOINT SPACING	4.4	1	4.4	4.4	100	0
377	MECHANICAL ANALYSIS OF SUBGRADE	4.4	1	4.4	4.4	10000000	0
999	TOTAL 18 KIP SINGLE AXLE LOADS TO DATE	4.4	6	3.6	4.9	100000001	101110000
16	LOCATION OF COMMERCIAL DRIVEWAY CONSTRUCTION	4.4	1	4.4	4.4	0	1
710	PREVENTIVE MAINTENANCE MEASURES	4.4	3	3.9	5.0	11	10
282	REDUCTION IN PLASTICITY INDEX BY STABILIZATION - LAYER	4.4	1	4.4	4.4	1000000000	0
1179	PERIODIC CRACK SPACING PROFILE FOR CRCP	4.4	2	4.0	4.8	11000000	0
580	TIME OF SAWING SAWED JOINT	4.4	1	4.4	4.4	10	0
497	TYPE OF CONCRETE FORMS	4.4	1	4.4	4.4	0	100000000

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
677	QUALITY TESTS DATA ON MATERIALS	4.4	1	4.4	4.4	10000 0
683	PERCENT CRUSHED FACE OF SURFACE AGGREGATE	4.4	1	4.4	4.4	0 100000
10	BEGINNING MILEPOINT - PROJECT, BRIDGE, ETC	4.4	6	3.7	5.0	10101011000 10000
1699	ANNUAL SERVICEABILITY INDEX RATING - PER 0.2 MI	4.4	6	3.1	5.0	11100000001 101000000
609	PERCENT OF AIR ENTRAINING USED IN CONCRETE PAVEMENT	4.4	5	3.1	5.0	101000010 100010000
1646	DESIGN HOURLY TRAFFIC (DHV)	4.4	5	3.5	5.0	1000000001100000110
657	BASE TRIAXIAL CLASS	4.4	12	3.7	5.0	1101011111011000010100
360	SUBGRADE TRIAXIAL CLASS/RAW	4.4	17	3.2	5.0	101111111111111111010
759	OVERLAY THICKNESS	4.4	13	3.0	5.0	1011111100110010100011
2	CONTROL	4.4	6	3.8	5.0	101011010 10000
736	DATE OF SEAL COATS	4.4	12	3.3	5.0	1011010001110010101111
387	SUBBASE THICKNESS	4.4	11	3.2	5.0	11001111010110100001
59	STOPPING SIGHT DISTANCE	4.4	1	4.4	4.4	0 10000000
335	SUBGRADE SOIL TYPE-SUBGRADE MATERIAL	4.4	21	3.7	4.8	1111111111111111111111
678	DEPTH OF SAWED JOINT	4.4	1	4.4	4.4	10 0
734	PROBABLE CAUSE OF DISTRESS REQUIRING REHABILITATION	4.4	2	3.7	5.0	10000000 100000
652	TYPE OF FINE AGGREGATE	4.4	5	3.7	5.0	1001011 100000000
707	ROUTINE MAINTAINANCE OPERATIONS	4.4	7	3.5	5.0	10010100010 100110
363	SUBGRADE E VALUE	4.4	1	4.4	4.4	1 0
685	SURFACE STIFFNESS COEFFICIENT	4.3	2	4.0	4.7	10100000000 0
660	SKID FACTOR OF SURFACE AGGREGATES	4.3	5	3.7	5.0	1110 100001
699	TENSILE STRENGTH OF REINFORCEMENT	4.3	1	4.3	4.3	100000000 0
733	BASIC PAVEMENT TYPE	4.3	18	3.2	5.0	1110101111111111111101
677	TYPE OF MATERIAL USED IN TRANSVERSE JOINT	4.3	1	4.3	4.3	100 0
629	TYPE OF HOT MIX USED	4.3	3	4.0	4.8	101000100 0
627	TYPE OF STABILIZATION - BASE	4.3	19	3.4	5.0	1111111111111111111001
861	ANNUAL MAINT COST OF SHOULDER BASE/LANE MILE	4.3	2	3.6	5.0	10100000000
1001	PROJECTED TRAFFIC COUNTS	4.3	2	3.6	5.0	01000000100
1181	PERCENT LANE MI OF PVMT WITH JOINT FAILURES	4.3	2	3.7	4.9	10000000 100000000

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
63	NUMBER OF LANES EACH DIRECTION	4.3	1	4.3	4.3	0 100000
429	DEPTH OF STABILIZED BASE	4.3	1	4.3	4.3	0100000000
973	RAINFALL INTENSITY	4.3	1	4.3	4.3	1000000 0
486	MODULUS OF ELASTICITY OF SURFACE	4.3	2	4.0	4.6	1 100
401	SUBBASE STIFFNESS COEFFICIENT	4.3	2	3.8	4.8	110000000 0
402	SUB-BASE TRIAXIAL CLASS	4.3	9	3.8	5.0	10100101111000010100
575	TYPE OF TRANSVERSE JOINT - CONCRETE PAVEMENT	4.3	3	3.5	4.8	100000100 1000000
5	HIGHWAY NUMBER	4.3	9	3.3	5.0	1011011 10010101
318	DENSITY OF EACH LAYER OF COMPACTED EMBANKMENT	4.3	1	4.3	4.3	10000000 0
205	SPECIFICATION ITEM USED - LAYER	4.3	1	4.3	4.3	0 10000000
480	SURFACE COURSE THICKNESS	4.3	18	2.9	5.0	1111101111 11110111
258	COMPRESSIVE STRENGTH - LAYER	4.3	2	3.6	4.9	10000000001000000000
420	BASE THICKNESS	4.3	21	2.4	5.0	111111111111111111111
210	LAYER DESIGN (TRENCH OR BLANKET TYPE)	4.3	11	3.7	4.9	101111001011001110000
554	CONCRETE FLEXURAL STRENGTH	4.3	8	3.5	5.0	11101000010 100110000
712	STATEMENT OF MAINTENANCE PROBLEMS	4.3	2	3.5	5.0	10001000 0
458	TRIAXIAL CLASSISFICATION OF STABILIZED BASE	4.3	1	4.3	4.3	10000000 0
1276	PROBABLE DISTRESS MECHANISMS	4.3	4	3.8	4.9	1000001000 10000001
538	METHOD OF CONSOLIDATION	4.3	2	3.5	5.0	0 101000000
1242	CURRENT ADT	4.2	21	3.1	5.0	111111111111111111111
1223	PERCENT LANE MI OF PVMT WITH SLIGHT WAVES,SAGS,HUMPS	4.2	1	4.2	4.2	1000000000 0
1224	PERCENT LANE MI OF PVMT WITH MODERATE WAVES,SAGS,HUMPS	4.2	1	4.2	4.2	1000000000 0
1225	PERCENT LANE MI OF PVMT WITH SEVERE WAVES,SAGS,HUMPS	4.2	1	4.2	4.2	1000000000 0
627	ASPHALT CONCRETE PAVEMENT - THICKNESS	4.2	2	3.9	4.6	0 1000100
477	TYPE OF SURFACING	4.2	21	3.2	5.0	111111111111111111111
824	COST OF HAUL FOR BASE MATERIAL	4.2	1	4.2	4.2	10000 0
976	WET DRY CYCLE INDEX	4.2	1	4.2	4.2	0 10000
1297	CONDITION SURVEY (BI-ANNUALLY)	4.2	2	4.0	4.5	10100000000 0
345	SURGRADE STABILIZATION - DEPTH	4.2	15	2.7	5.0	110110110011111111100

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
381	POTENTIAL VERTICAL RISE (FROM SWELLING CLAY)	4.2	9	3.6	5.0	1100100011101100010
410	AVG PI OF SUB-BASE MATL	4.2	2	3.8	4.6	11 0
217	THICKNESS - LAYER	4.2	20	2.8	4.8	111111111111111011111
598	AMOUNT OF STEEL	4.2	4	2.6	5.0	110000000 1000010
1169	PERCENT LANE MI OF PVMT WITH CONTRACTION CRACKS	4.2	3	2.7	5.0	10000010 100000000
1101	INITIAL SERVICEABILITY INDEX	4.2	4	3.5	5.0	10000011 100000
822	COST FOR EACH STABILIZED BASE LAYER	4.2	1	4.2	4.2	10000 0
254	WET BALL MILL OF COARSE AGGREGATES - LAYER	4.2	4	3.8	4.6	1000101 10000
772	TIME INTERVAL FOR CLEANING AND REPAIRING JOINTS	4.2	2	3.8	4.6	10000100 0
4	COUNTY	4.2	5	3.1	5.0	1001010 100010000
1000.	TOTAL EQUIV 18K SINGLE AXLE APPLIED TO DATE	4.2	2	4.1	4.3	10000100000 0
1051	PERCENT TRUCKS IN AADT	4.2	20	2.4	5.0	11111111111111111111
136	ORIGINAL PAVEMENT DEPTH - REVISED PVMT	4.2	1	4.2	4.2	1000000000 0
508	DOSAGE RATE OF TYPE A OR D ADMIXTURE	4.2	1	4.2	4.2	1000000 0
714	DATE OF EACH MAJOR REPAIR	4.2	1	4.2	4.2	01000000000
715	TYPE OF EACH MAJOR REPAIR	4.2	1	4.2	4.2	01000000000
875	GENERAL DESCRIPTION OF CONSTRUCTION JOB	4.2	2	3.9	4.5	10000000001000000000
224	MATERIAL TYPE - LAYER	4.2	21	3.3	4.8	111111111111111111111
283	MOISTURE IN LAYER	4.2	1	4.2	4.2	1000 0
548	WAS PONDING USED IN INITIAL CONSTRUCTION	4.2	1	4.2	4.2	1 0
184	DRAINAGE TYPE	4.2	4	3.6	5.0	0 11010010
992	PREDICTED TRAFFIC LOADS (18K EQUIV)	4.2	18	2.8	5.0	111111111111110111100
768	LOCATION OF CONCRETE FAST REPAIR GT 4 CY	4.2	2	3.6	4.8	1 1
1034	DESIGN VOLUME	4.2	15	3.0	5.0	1011011011111111110
533	CONCRETE WATER/CEMENT RATIO	4.2	9	3.1	5.0	111111100001100000000
1072	CONDITION OF SIGNALS	4.2	1	4.2	4.2	1000000000 0
342	SPECIFICATION ITEM USED FOR STABILIZING MATL	4.2	1	4.2	4.2	10 0
326	PLASTICITY INDEX OF BORROW MATERIAL	4.2	1	4.2	4.2	10000000 0
7	PROJECT NO.	4.2	2	3.9	4.4	1010000 0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
531	CONCRETE CEMENT FACTOR	4.2	8	2.8	5.0	11001000010110101000 0
419	NUMBER OF LAYERS - BASE	4.2	11	3.0	5.0	1010100110111010110 0
465	AVG LL OF BASE MATL	4.2	6	3.3	4.8	110000011 110000
588	PERCENT OF REINFORCEMENT	4.2	7	3.5	5.0	10100001010100010000 1
1148	CRACK RATING	4.2	5	2.0	5.0	110000011 100000
286	PERCENT OPTIMUM MOISTURE AFTER PLACEMENT - LAYER	4.2	1	4.2	4.2	1000000 0
537	MIXING TIME	4.2	2	3.3	5.0	1000010 0
1117	INITIAL SKID NUMBER	4.2	3	3.1	4.7	10000001 100000
549	CONCRETE DENSITY	4.1	1	4.1	4.1	0 1
574	TYPE OF MATERIAL USED IN LONGITUDINAL JOINTS	4.1	2	3.8	4.5	110 0
636	TEMPERATURE OF ASPHALT IN ACP MIX	4.1	4	3.9	4.7	1001000000100000010 0
65	LANE CODE - MAIN, SHOULDER, FRONTAGE, ETC	4.1	7	2.9	5.0	10010001000 100000111
380	SWELLING CLAY PROBABILITY	4.1	4	3.0	5.0	0 101100010
430	PERCENT CONTENT OF STABILIZATION - BASE	4.1	8	3.4	4.9	11001000101 1110000
1016	ATHWLD (AVERAGE TEN HEAVIEST WHEEL LOADS DAILY)	4.1	14	2.5	5.0	1110111001110111110 0
336	SUBGRADE CLASSIFICATION	4.1	9	2.9	5.0	1010010011010110100000
790	COST OF INITIAL PAVEMENT STRUCTURE/SQ YD	4.1	1	4.1	4.1	1 0
1053	PERCENT BUSES IN AADT	4.1	2	3.5	4.8	1000 1
1041	INITIAL ADT	4.1	9	3.3	5.0	1111100001110001000 0
721	TYPE OF EACH REHABILITATION	4.1	2	3.5	4.8	1000 100000
1202	PERCENT LANE MI OF PVMT WITH PUMPING SLABS	4.1	2	3.4	4.9	10000000 100000000
1185	SPALLING SURVEY EACH TWO YEARS - CONC PVT	4.1	1	4.1	4.1	10000000 0
559	CONCRETE MODULUS OF ELASTICITY	4.1	3	3.7	4.5	100001000 1000000
50	TRAFFIC CONTROL DEVICES	4.1	1	4.1	4.1	0 10000000
1077	DATE OF OBSERVATION OF FIRST SURFACE FAILURE	4.1	4	4.0	4.5	10001000101 0
315	METHOD OF COMPACTION OF EMBANKMENT	4.1	2	3.6	4.6	10010000000 0
1044	END OF DESIGN PERIOD ADT	4.1	1	4.1	4.1	1000 0
1197	PERCENT LANE MI OF PVMT WITH RUTTING	4.1	3	2.9	4.9	10000000 100100000
418	TYPE OF BASE	4.1	21	3.1	5.0	111111111111111111111

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
140	PREDICTED PAVEMENT LIFE	4.1	14	3.0	5.0	10101101010111111111010
347	PERCENT CONTENT OF STABILIZATION - SUBGRADE	4.1	1	4.1	4.1	1000000000 0
370	IS SUBGRADE SOIL PERVIOUS OR IMPERVIOUS	4.1	1	4.1	4.1	100000 0
645	TYPE OF ASPHALT BINDER	4.1	1	4.1	4.1	1000000 0
909	IDENTIFICATION OF SUPPLIER - AGGREGATE (INTERMEDIATE)	4.1	2	3.5	4.7	10 100
1038	DATE OF ADT	4.1	1	4.1	4.1	1000000000 0
1150	CRACK WIDTH	4.1	2	3.7	4.5	11000000000 0
437	TYPE OF BASE MATERIAL - SHOULDER	4.1	6	3.4	4.9	10101000010 1010
256	STRENGTH CLASSIFICATION OF EACH LAYER	4.1	5	3.5	4.8	10000001001 100001
1004	20 YEAR PROJECTED ADT (D-10)	4.1	3	3.6	4.6	1000000110000000000
640	TYPE OF ASPHALT USED FOR SURFACE TREATMENT	4.1	6	2.6	5.0	100100000111001000000
464	AVG PI OF BASE MATL	4.1	7	3.2	4.9	110000010 110110000
1140	DYNAFLECT DEFLECTION - EA 0.2 MI. BI ANNUALLY	4.1	2	3.2	5.0	10000000000 1000000
860	ANNUAL MAINT COST OF TRAFFIC LANES BASE/LANE MILE	4.1	2	3.2	5.0	10 1000000
1096	DATE OF SERVICEABILITY INDEX RATING	4.1	3	3.4	5.0	100000011 0
649	AGGREGATE TYPE	4.1	17	2.8	5.0	111100101111111101111
1512	DESIGN LOAD	4.1	9	1.8	5.0	10101000110 11100010
1027	MAXIMUM WEIGHT OF OVERLOAD	4.1	1	4.1	4.1	100000 0
358	COMPRESSIVE STRENGTH - STABILIZED SUBGRADE	4.1	2	3.6	4.6	10000000 100000000
185	DRAINAGE ADEQUACY	4.1	5	2.9	5.0	11010000010 10000
1068	ANNUAL INSPECTION DESCRIPTION	4.1	11	2.7	5.0	1100011000111001101
310	TRIAXIAL CLASS OF FOUNDATION COURSE	4.1	1	4.1	4.1	1000000000 0
1061	85 PERCENTILE SPEED	4.1	1	4.1	4.1	0 10000
436	TYPE OF BASE MATERIAL - TRAFFIC LANE	4.1	4	3.4	4.9	101000001 10
922	TEMPERATURE DURING PAVING	4.1	6	3.1	5.0	1101001101000
852	DATE OF ANNUAL MAINTENACNE COST	4.1	1	4.1	4.1	1000000000 0
264	PHYSICAL QUALITIES OF MATERIALS - LAYER	4.1	5	3.1	4.9	100011010 100000
422	BASE THICKNESS - SHOULDER	4.1	9	2.9	5.0	11101100010 101010
628	ASPHALT STABILIZATION BASE - THICKNESS	4.1	1	4.1	4.1	0 1

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
833	COST PER TYPE OF ACP	4.1	1	4.1	4.1	10000 0
1252	AMOUNT OF REPAIRS CAUSED BY SUBGRADE FAILURE	4.1	3	3.7	4.6	01010100000
1002	FIVE YEAR PROJECTED ADT	4.0	2	3.6	4.5	01000000100
717	DATE OF EACH SURFACE MAINTENANCE	4.0	10	3.1	5.0	10101110010110010000l
854	MAINTENANCE COST PER LANE MI. PER YEAR	4.0	21	3.3	4.9	111111111111111111111
638	GRADATION OF MIXTURE FOR BASE	4.0	5	3.2	4.8	1100000011000010000
565	JOINT SPACING - JOINTED CONCRETE PAVEMENT	4.0	6	3.2	5.0	10110011000 100000000
209	MATERIAL CLASSIFICATION - LAYER	4.0	1	4.0	4.0	100000 0
108	THICKNESS OF SHOULDER SURFACING	4.0	9	2.7	5.0	111000010111000100010
546	AVERAGE SLUMP USED IN CONC PVT	4.0	9	3.1	5.0	1111000110 101010000
1010	LOAD FREQUENCY DESIGN FACTOR	4.0	3	4.0	4.1	0 100101000
625	SPECIFICATION ITEM USED FOR ACP	4.0	3	3.5	5.0	1000000010 10000
1086	SHOULDER CONDITION - CRACKS	4.0	2	3.6	4.5	11000000000 0
359	SUBGRADE STIFFNESS COEFFICIENT	4.0	8	3.0	4.8	10110000011 101100000
849	COST PER AGGREGATE TYPE AND GRADE FOR SEAL COATS	4.0	1	4.0	4.0	10000 0
659	SURFACE AGGREGATE POLISH VALUE	4.0	15	2.6	4.9	11000111011111111101
755	DATE OF OVERLAY CONSTRUCTION	4.0	14	2.6	5.0	101111110111001110010
954	MAXIMUM FROST DEPTH	4.0	4	3.4	4.6	100000101 10000000
1030	ACTUAL WHEEL LOADS AS RECORDED BY WEIGH IN MOTION SCALE	4.0	1	4.0	4.0	100 0
887	TYPE OF FINISHING EQUIPMENT	4.0	2	3.6	4.4	1000000 100000000
1053	AMOUNT OF REPAIRS CAUSED BY BASE FAILURE	4.0	7	2.8	5.0	1101000001010100100
1040	ESTIMATED AVERAGE ANNUAL ADT	4.0	4	3.6	4.4	10 101000010
760	PRIMARY REASON FOR OVERLAYING (DEVELOP CODE)	4.0	1	4.0	4.0	10000000 0
938	ANNUAL TEMPERATURE RANGE	4.0	4	3.0	4.9	11001010000000
633	STABILITY OF HMAC	4.0	13	3.1	5.0	11010101111110110001
836	COST PER AGGREGATE TYPE AND GRADE FOR ASPH SURF TREAT	4.0	1	4.0	4.0	10000 0
374	SUBGRADE FRICTION FACTOR	4.0	1	4.0	4.0	0 100000000
385	CLASSIFICATION OF SUBBASE	4.0	1	4.0	4.0	01000000000
391	TYPE OF SUBBASE TREATMENT	4.0	1	4.0	4.0	0 100

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
395	PERCENT SUBBASE STABILIZATION - SHOULDER	4.0	1	4.0	4.0	1000000000	0
158	GRADE SEPARATION	4.0	1	4.0	4.0	0	1
431	PERCENT OF BASE STABILIZATION - SHOULDER	4.0	1	4.0	4.0	1000000000	0
511	TYPE RETARDER	4.0	1	4.0	4.0	1000000	0
512	IDENTIFICATION OF SUPPLIER - RETARDER	4.0	1	4.0	4.0	1000000	0
513	DOSAGE RETARDER	4.0	1	4.0	4.0	1000000	0
520	COARSE AGGREGATE TYPE - CONCRETE	4.0	1	4.0	4.0	1000000000	0
521	FINE AGGREGATE - CONCRETE	4.0	1	4.0	4.0	1000000000	0
562	STIFFNESS OF LAYER	4.0	1	4.0	4.0	10000000000	0
544	TYPE FLOAT	4.0	1	4.0	4.0	1000000	0
585	TYPE OF SEAL USED AT SHOULDERS	4.0	2	3.0	5.0	0	100000010
635	TEMPERATURE OF AGGREGATES IN ACP MIX	4.0	1	4.0	4.0	1000000	0
651	TYPE OF INTERMEDIATE AGGREGATE	4.0	1	4.0	4.0	10	0
674	ACP LAB DENSITY	4.0	1	4.0	4.0		01000000000
748	ASPHALT GRADE - SEALS, PRIMES, CURING	4.0	1	4.0	4.0		01000000000
800	LABOR COST - CONSTRUCTION	4.0	1	4.0	4.0	0	1000
883	PAVING TRAIN EQUIP (SPREADER-FINISHER-ETC)	4.0	1	4.0	4.0	1000000	0
951	AVG DURATION OF PLUS 90 DEGREE PERIODS	4.0	1	4.0	4.0	1000000	0
952	AVG DURATION OF BELOW FREEZING PERIODS	4.0	1	4.0	4.0	1000000	0
956	AVERAGE FROST HEAVE IN INCHES	4.0	1	4.0	4.0	1	0
1018	AVERAGE HEAVY TRUCK TRAFFIC DURING THAW CYCLE	4.0	1	4.0	4.0	100000	0
1036	PERCENT OF THEORETICAL CAPACITY - ANNUALLY	4.0	1	4.0	4.0	1000000000	0
1037	DATE OF PERCENT OF THEORETICAL CAPACITY	4.0	1	4.0	4.0	1000000000	0
1069	CROSS-SLOPE TRANSITION RATE	4.0	1	4.0	4.0	100000	0
1087	SHOULDER CONDITION - PAVEMENT EDGE	4.0	1	4.0	4.0	1000000000	0
1230	PAVEMENT HEAVING (FAILURES)	4.0	1	4.0	4.0	0	10
1231	PAVEMENT HEAVING (RAVELING)	4.0	1	4.0	4.0	0	10
1232	PAVEMENT HEAVING (ROUGH)	4.0	1	4.0	4.0	0	10
1233	PAVEMENT HEAVING (SLICK)	4.0	1	4.0	4.0	0	10

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
1259	FRICTION FACTOR FOR WET PAVEMENT	4.0	1	4.0	4.0	0 10
1111	ANNUAL SKID RESISTANCE PROFILE	4.0	9	2.9	5.0	1100010111001100001
470	POROSITY - BASE	4.0	1	4.0	4.0	1 0
379	SWELLING CLAY PARAMETER	4.0	5	3.0	4.7	1000000001111000000000
549	MEAN ACTUAL ROAD DENSITY - LAYER	4.0	4	3.2	4.8	1000100100 10000
699	PERCENT WATER IN ASPHALTIC CONCRETE MIX	4.0	3	3.7	4.4	1010000 10
713	TYPE OF REPAIRS REQUIRED	4.0	9	2.5	5.0	10010011 111100100
644	PERCENT ASPHALT (BY WEIGHT OF AGGREGATE)	4.0	14	1.6	4.9	1111101011111011000010
343	TYPE OF SUBGRADE PREPARATION	4.0	14	2.3	4.8	1001101011111111011010
1080	TYPE OF DETERIORATION (OBSERVED EVERY 6 MONTHS)	4.0	6	2.0	5.0	1000011010 110000000
924	LOW DAILY TEMPERATURE DURING CONSTRUCTION	4.0	2	4.0	4.0	1001000000 0
268	LAYER TRIAXIAL CLASSIFICATION	4.0	11	3.2	4.5	111100111 10110010
1165	PERCENT LANE MI OF PVMT WITH ALLIGATOR CRACKS	4.0	3	2.8	4.6	10010000000 100000
432	PERCENT LIME FOR BASE STABILIZATION	4.0	2	2.9	5.0	10010000000 0
572	TYPE OF LONGITUDINAL JOINT - CONCRETE PAVEMENT	4.0	6	3.2	4.8	1110000010 1000001
61	NUMBER OF LANES	4.0	21	3.5	4.5	111111111111111111111
344	TYPE OF STABILIZATION - SUBGRADE	3.9	19	2.7	5.0	11111111111111101111
334	SPECIFICATION ITEM USED FOR SUBGRADE PREPARATION	3.9	3	3.7	4.1	10 10001000
53	SPECIAL LANES FOR MASS TRANSIT	3.9	1	3.9	3.9	100000000 0
187	DESIGN RUNOFFS IN SIDE ROAD DITCHES	3.9	1	3.9	3.9	10000000 0
637	ASPHALT TYPE	3.9	14	2.8	5.0	1111000111110101110
1375	PREVALENT DISTRESS TYPES	3.9	4	3.4	5.0	11000000000 100000001
141	PREDICTED LIFE OF PAVEMENT SURFACE	3.9	3	3.5	4.2	100000000 10001000
1157	NUMBER OF TRANSVERSE CRACKS AT DECISION TO OVERLAY	3.9	1	3.9	3.9	10000000 0
1015	MAXIMUM TOTAL LOAD	3.9	11	2.9	5.0	1000110001111111001010
757	OVERLAY TYPE	3.9	11	2.5	5.0	1011101001010011010001
667	RATE OF ASPHALT USED FOR SURFACE TREATMENT (GAL/S.Y.)	3.9	9	2.0	5.0	10101100111000000110
325	TRIAXIAL CLASS OF BORROW MATERIAL	3.9	1	3.9	3.9	10000000 0
1058	LANE TRAFFIC DISTRIBUTION (PERCENT)	3.9	9	3.0	4.8	11010001010 1110001

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
664	RATES OF APPLICATION	3.9	3	3.1	4.9	100000000	110000
1137	DYNAFLECT DEFLECTION (SURFACE)	3.9	9	3.0	5.0	111010101000110100	
626	ACP PAVING DESIGN	3.9	9	2.6	4.9	1100111001	100001100
463	PLASTIC LIMIT OF BASE MATERIAL	3.9	1	3.9	3.9	10000000	0
1151	CRACK SPACING PATTERN -SAMPLE- UNIFORMITY AND SPACING	3.9	9	2.4	4.9	11000001011001001101	
454	AGGREGATE GRADE	3.9	10	3.1	5.0	111000101111000011000	
596	YIELD STRENGTH LONGITUDINAL STEEL	3.9	1	3.9	3.9	1000000000	0
1266	LOCATIONS WITH TWO OR MORE ACCIDENTS PER YEAR	3.9	1	3.9	3.9	100000	0
455	BASE STIFFNESS COEFFICIENT - TRAFFIC LANE	3.9	5	3.1	4.7	10110000001	1000000
196	DEPTH OF DITCH BELOW SUBGRADE (OUTSIDE)	3.9	2	3.1	4.7	100000	100000
1020	FREQUENCY OF LOADS EXCEEDING 60,000	3.9	1	3.9	3.9	0	1
669	RATE OF AGGREGATE USED FOR SURFACE TREATMENT	3.9	7	1.9	5.0	10101000101000000110	
1092	ROUGHNESS MEASUREMENT - AVG OF FA PROJECT-ANNUALLY	3.9	6	1.7	4.8	11100101000	1000
168	SUBGRADE TRANSVERSE SLOPE	3.9	2	3.8	4.0	11000000000	
49	ILLUMINATION	3.9	1	3.9	3.9	0	10000000
307	TYPE OF FOUNDATION MATERIAL STABILIZATION	3.9	2	3.6	4.1	10000001000	0
593	TRANSVERSE STEEL TYPE	3.9	1	3.9	3.9	1000000000	0
450	TYPE OF COARSE AGGREGATE	3.9	4	3.0	5.0	1000010	100100000
1054	PERCENT CARS IN AADT	3.9	4	3.5	4.8	100010001000000001	
390	WIDTH OF SUBBASE	3.9	2	3.1	4.7	1000000000	10000
487	STABILITY OF SURFACE	3.9	1	3.9	3.9	0	10
916	SPECIAL CONSTRUCTION METHODS USED	3.9	3	2.1	5.0	11010	0
482	GRADATION OF SURFACE	3.9	2	3.0	4.8	01000000010	
1195	AMOUNT OF RUTTING	3.9	4	2.7	4.5	11000000000	10000010
1112	SKID RESISTANCE PROFILE AFTER FIRST YEAR	3.9	1	3.9	3.9	10000000	0
1141	SURFACE CURVATURE INDEX - ACP	3.9	2	3.1	4.6	100000000	100000000
1201	PUMPING (PERCENT OF LENGTH)	3.9	3	2.7	4.9	100000100	10
31	DATE OPENED TO TRAFFIC	3.9	8	2.9	5.0	11100111001100000000	
441	PERCENT -40 MESH MATERIAL IN BASE	3.9	2	3.2	4.6	1000000000	10000

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
353	DENSITY OF SUBGRADE MATERIAL AT CONSTRUCTION	3.9	8	2.2	4.7	11101010110000010000
1170	PERCENT LANE MI OF PVMT WITH REFLECTION CRACKS	3.9	2	2.7	5.0	10000010 0
500	CONCRETE PVT DESIGN MIX	3.9	8	2.5	5.0	1111100010 100001000
384	SUBBASE SOIL TYPE	3.9	18	2.8	5.0	11111111010101111111
1254	AMOUNT OF REPAIRS CAUSED BY SURFACE FAILURES	3.9	4	3.3	5.0	10100000 10000100
862	ANNUAL MAINT COST OF TRAFFIC LANES SURFACE/LANE MILE	3.9	6	2.4	5.0	101001011010
541	CURING TIME - CONCRETE PAVEMENT	3.9	1	3.9	3.9	1000000000 0
452	TENSILE STRENGTH - STABILIZED BASE	3.9	2	3.3	4.4	101 0
1331	PERCENT TANDEM AXLES IN ATHWLD	3.9	6	2.5	5.0	100001100110100
109	NUMBER OF LAYERS - SHOULDERS	3.9	1	3.9	3.9	01000000000
260	FLEXURAL STRENGTH - LAYER	3.9	1	3.9	3.9	1000000000 0
132	DISTANCE FROM C/L NEW TO C/L ORIG - REVISED PVMT	3.9	1	3.9	3.9	1000000000 0
206	MONTH AND YEAR OF CONSTRUCTION - LAYER	3.9	20	2.6	4.9	11111111111111110111
850	OPERATIONAL COST	3.9	2	3.7	4.0	0 110000000
35	SEASONAL TRAFFIC USE (SUCH AS GRAIN HAULING)	3.8	1	3.8	3.8	0 10000
471	ABSORPTION PERCENT OF BASE	3.8	1	3.8	3.8	0 10000
68	LANE TERMINATION METHOD	3.8	1	3.8	3.8	100000 0
884	TYPE OF VIBRATOR USED	3.8	3	3.2	4.8	1000100 1000000
29	TYPE OF FACILITY (URBAN - RURAL)	3.8	15	2.2	5.0	1111011011111110010
60	PASSING SIGHT DISTANCE	3.8	2	3.6	4.1	0 10000100
720	DATE OF EACH REHABILITATION EVENT	3.8	5	2.4	4.7	1101000 100001
683	COHESIOMETER TEST RESULTS	3.8	2	3.8	3.9	1000000 10000000
442	PERCENT -.005MM IN -40 MATL OF BASE LAYER	3.8	1	3.8	3.8	1 0
382	RATE OF SWELL (FROM SWELLING CLAY SUBGRADE)	3.8	2	3.6	4.1	100000001 0
563	STIFFNESS COEFFICIENT - LAYER	3.8	4	2.9	4.3	110000001 100000
33	TRAVELWAY WIDTH	3.8	4	2.8	4.8	10000101000 10000
351	COMPACTION RATIO - SUBGRADE	3.8	1	3.8	3.8	10000000 0
411	AVG LL OF SUB-BASE MATL	3.8	1	3.8	3.8	10 0
866	ANNUAL MAINT COST OF MEDIAN BARRIER/MILE	3.8	1	3.8	3.8	10 0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
219	STABILIZATION TYPE - LAYER	3.8	9	2.9	4.8	10100001111010101000
1174	PERCENT LANE MI OF PVMT WITH RANDOM CRACKING	3.8	2	2.7	4.9	10000000 100000000
910	IDENTIFICATION OF SUPPLIER - AGGREGATE (FINE)	3.8	4	3.1	4.4	1001000011 0
302	FOUNDATION MATERIAL TYPE	3.8	1	3.8	3.8	1000 0
66	LANE WIDTH	3.8	21	2.9	4.5	11111111111111111111
111	SHOULDER MATERIALS	3.8	4	2.1	4.8	1001000 10100000
352	SUBGRADE DENSITY CONTROLLED (YES-NO)	3.8	1	3.8	3.8	01000000000
424	FLEX BASE - DEPTH	3.8	9	2.7	5.0	10100001101000001111
698	MIX AIR VOIDS	3.8	1	3.8	3.8	1000 0
750	CURING TIME OF PRIME COAT	3.8	1	3.8	3.8	1000000 0
459	BASE MODULUS	3.8	1	3.8	3.8	10 0
972	FREQUENCY OF RAINFALL	3.8	1	3.8	3.8	0 10000000
1029	SURVEY OF ACTUAL GROSS VECHILE WTS - FM HWYS	3.8	2	3.5	4.1	101000 0
1106	SERVICEABILITY INDEX AFTER EACH SEAL COAT	3.8	1	3.8	3.8	10000000 0
1286	MAXIMUM LIQUID LIMIT - BASE	3.8	1	3.8	3.8	10000000000 0
321	COMPACTION RATIO - BORROW MATERIAL	3.8	1	3.8	3.8	10000000 0
1172	PERCENT LANE MI OF PVMT WITH DIAGONAL CRACKING	3.8	2	2.7	4.9	10000000 100000000
1348	DESIGN VEHICLE TYPE	3.8	11	2.7	5.0	10100110011111010110
94	DATE OF SHOULDER CONSTRUCTION	3.8	1	3.8	3.8	1000 0
396	RATE OF APPLICATION FOR SUBBASE MATERIAL STABILIZER	3.8	1	3.8	3.8	0 1000000
522	AVERAGE CAF - CONCRETE PAVEMENT	3.8	6	2.1	4.9	10001000110 100010000
1259	DESIGN SPEED	3.8	8	2.5	4.8	11000000001110011001
186	SURFACE RUNOFF ADEQUACY	3.8	4	3.2	4.7	10000000000 110000001
561	SURFACE TEXTURE OF CONCRETE PVT	3.8	12	3.0	4.9	1111100101 110101010
1249	DENSITY OF SUBGRADE MATERIAL YEARLY	3.8	2	3.3	4.2	11000000 0
923	HIGH DAILY TEMPERATURE DURING CONSTRUCTION	3.8	3	3.6	4.0	1001000001 0
447	DENSITY OF BASE MATERIAL	3.8	8	2.7	4.9	10110000101100001001 0
571	TYPE OF MATERIAL USED IN CONTRACTION JOINTS	3.8	2	3.0	4.5	110 0
107	TYPE OF SHOULDER SURFACING	3.8	13	1.2	5.0	11101101111100001101 0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
211	NUMBER OF LAYERS	3.8	20	2.6	5.0	11111111011111111111
1260	ACCIDENT FREQUENCY	3.8	9	2.4	4.7	1110100001 10001101
1109	SKID RESISTANCE HISTORY	3.8	15	1.7	4.9	1111001110111110110101
212	SEQUENCE OF LAYERED CONSTRUCTION	3.7	6	2.6	5.0	11010000010 1100
996	18 KIP EQUIV. (0-10)	3.7	2	2.5	5.0	10010000000 0
220	AMOUNT OF STABILIZER - LAYER	3.7	5	2.7	4.8	100000101000101000
1108	DATE OF SKID RESISTANCE MEASUREMENT	3.7	3	2.8	4.4	10000000011000000000
303	FOUNDATION THICKNESS	3.7	1	3.7	3.7	1000 0
357	TENSILE STRENGTH - LAYER	3.7	2	2.9	4.6	100000000 100000
662	FREEZE-THAW SOUNDNESS OF SURFACE AGGREGATES	3.7	2	3.2	4.3	100000100 0
1180	CONDITION OF JOINTS ON JOINT CONC PVMT (SUBJECTIVE RATE)	3.7	3	2.2	4.8	100000100 1
1832	AXLE LOAD INFORMATIONS	3.7	5	2.2	4.3	01101100001
364	SUBGRADE K VALUE	3.7	3	2.8	4.4	10000000011000000000
355	CURING TIME OF EACH LAYER	3.7	2	2.8	4.7	101000000 0
453	COMPRESSIVE STRENGTH (UNCONFINED) - STABILIZED BASE	3.7	2	3.4	4.1	10000100 0
181	DEPTH OF SOIL MOISTURE CHANGE	3.7	1	3.7	3.7	0 100000
367	AVG PI OF SUBGRADE MATL	3.7	14	2.1	4.8	111110111111110000
526	SIEVE ANALYSIS OF AGGREGATE FOR CONC PVT	3.7	5	2.7	4.7	1011010010 0
738	TYPE OF SEAL COAT USED	3.7	5	2.1	5.0	110000000 1100010
101	PAVED SHOULDER WIDTH	3.7	3	3.1	4.9	10000101000 0
510	VOLUME OF AIR (PERCENT)	3.7	2	3.1	4.3	1000000100000000
1152	PERCENT LANE MI OF PVMT WITH TRANSVERSE CRACKING	3.7	6	3.1	4.6	110000001000100101
415	SPECIFICATION ITEM USED FOR BASE	3.7	5	3.1	4.5	10011 10010
416	DATE BASE PLACED	3.7	2	3.4	4.0	10000000 10000
699	CONCRETE PLANT LOCATION	3.7	2	3.6	3.8	1000000 1
646	ASPHALT CONCRETE ADDITIVES	3.7	5	3.0	4.8	1000000100 100010010
12	LENGTH OF SEGMENT	3.7	2	3.5	3.9	1000010 0
47	DEPTH OF COVER NEEDED	3.7	1	3.7	3.7	01000000000
178	PREVIOUS SOIL TEST IN VICINITY	3.7	1	3.7	3.7	01000000000

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
749	ASPHALT RATE - SEALS, PRIMES, OR CURING	3.7	5	1.9	4.9	11000001100100000000
250	STANDARD DEVIATION OF ACTUAL ROAD DENSITY - LAYER	3.7	1	3.7	3.7	0 10000
137	CORE THICKNESS OF PAVEMENT	3.7	2	3.6	3.8	100 1000000
372	SUBGRADE SOIL CONSTANTS	3.7	2	3.3	4.1	101000000000
1024	RECORD OF APPROVED OVERLOADS	3.7	2	3.3	4.0	10000000 100000
208	PAVEMENT LAYER TYPE	3.7	1	3.7	3.7	1000000000 0
960	AVERAGE NUMBER OF WET FREEZE THAW CYCLES PER YEAR	3.7	1	3.7	3.7	0 100000
1192	ANNUAL TEXTURE DEPTH PROFILE	3.7	2	3.2	4.2	11000000000 0
825	COST OF SURFACE/LANE MILE	3.7	9	2.6	4.8	110011000 10111010
246	DENSITY - LAYER	3.7	9	2.3	5.0	111011100 100110000
967	TOTAL RAINFALL PER MONTH (INCHES) BY COUNTY	3.7	1	3.7	3.7	1000000000 0
213	LAYER NUMBER	3.7	20	1.8	5.0	11111111101111111111
819	COST OF BASE/SQ. YD.	3.7	2	3.2	4.1	1000000 10000
1005	20 YEAR PROJECTED ADT (DISTRICT ESTIMATE)	3.7	1	3.7	3.7	10000000 0
179	SOIL PROFILE WITH SOIL CLASSIFICATIONS	3.7	5	2.9	4.0	10000101000 100100
667	EXPANSION JOINT SPACING - CONCRETE PAVEMENT	3.7	3	3.0	4.6	1010000010 0
167	PAVEMENT CROSS SLOPE	3.7	13	2.5	4.5	11111000011110110100
1304	COST OF EACH REPAIR	3.7	1	3.7	3.7	0 10000000
368	AVG LL OF SUBGRADE MATL	3.7	8	2.1	4.8	11100111 101000000
348	PERCENT LIME FOR SUBGRADE STABILIZATION	3.7	8	2.6	5.0	10011001001101100000
1240	FREQUENCY OF BLOW-UPS	3.7	3	2.1	4.9	100 100000001
1114	SKID NUMBER OF SURFACE - ANNUALLY	3.7	8	1.8	5.0	10100000101 10001101
1019	NUMBER OF WHEEL LOADS PER MONTH GT 14,000 LBS	3.6	3	2.8	4.4	10010000 100000000
959	AVERAGE NUMBER OF FREEZE-THAW CYCLES PER YEAR	3.6	19	1.8	4.5	11111111111111111010
686	TYPE OF REINFORCEMENT	3.6	10	1.1	4.6	11011101011 10001
524	L.A. ABRASION FOR COARSE AGGREGATE	3.6	6	2.0	4.8	1010110 100010000
731	DATE OF LAST MAJOR REHABILITATION	3.6	2	2.8	4.5	10 100000000
820	COST OF BASE/TON	3.6	5	2.6	4.6	100010001 10010
1023	PERCENT OF OVERLOADS	3.6	4	2.9	4.1	11100000 100000000

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
1138	DEFLECTION - YEAR	3.6	7	2.1	4.9	11010001011	1000000
752	LEVEL-UP DATE	3.6	1	3.6	3.6	1	0
1102	PRESENT SERVICEABILITY INDEX	3.6	11	1.8	5.0	1101010111100110100	
1143	STANDARD DEVIATION - SURFACE CURVATURE INDEX	3.6	2	2.8	4.4	100000000	100000000
874	DATE OF STARTING WORK	3.6	2	3.3	4.0	1000000	10000000
473	PRESSURE SLAKING VALUE OF SYNTHETIC COURSE AGGREGATE	3.6	1	3.6	3.6	10000000	0
403	SOIL SUPPORT VALUE - TRIAXIAL CLASS	3.6	2	3.4	3.8	1	10
425	BASE WIDTH	3.6	5	3.2	4.1	10000001000110001000	
1083	PAVEMENT RATING SCORE - PROJECT 151	3.6	1	3.6	3.6	1000	0
328	LIQUID LIMIT OF BORROW MATERIAL	3.6	1	3.6	3.6	10000000	0
993	18KSA FUTURE 20YR DESIGN PERIOD	3.6	4	2.3	4.2	10100000000	1100000
100	OUTSIDE SHOULDER WIDTH	3.6	9	2.6	4.7	11001110000100100100	
182	GROUND WATER TABLE LEVEL	3.6	9	2.1	4.5	1111001000	11100000
1163	PERCENT LANE MI OF PVMT WITH RANDOM LONGITUDINAL CRACKS	3.6	3	2.7	4.6	10000000	100100
284	OPTIMUM MOISTURE DENSITY BY LAYERS	3.6	2	2.3	4.9	100	1000
848	SEAL COAT COST/SQ. YD.	3.6	2	3.3	4.0	1100000000	0
539	CURING METHOD - CONCRETE PAVEMENT	3.6	7	1.9	4.9	1100100011 0	101000000
183	DRAINAGE CONDITIONS	3.6	18	2.6	4.5	11111111111111010011	
613	TYPE TIE BAR STEEL	3.6	2	3.2	4.0	1000000	10000000
144	PAVEMENT POROSITY	3.6	1	3.6	3.6	1	0
388	DEPTH OF SUBBASE	3.6	4	2.8	4.1	1001100000	10
1116	LATEST SKID NUMBER PER LANE EACH .5 MI	3.6	1	3.6	3.6	1	0
131	TIME ELAPSE BETWEEN EARTHWORK AND PAVING	3.6	1	3.6	3.6	1000	0
106	SUBBASE WIDTH - SHOULDER	3.6	1	3.6	3.6	1000000000	0
693	ORIGINAL PENETRATION OF ASPHALT	3.6	1	3.6	3.6	1000000	0
762	ESTIMATED MIN TIME UNTIL NEXT OVERLAY	3.6	1	3.6	3.6	0	1000000000
888	TYPE OF ASPHALT CONC PLACEMENT EQUIPMENT	3.6	3	3.4	4.0	1010100000	0
105	BASE WIDTH - SHOULDER	3.6	1	3.6	3.6	1000000000	0
695	CONCRETE PAVING METHOD (SLIP FORM OR FIXED FORM	3.6	1	3.6	3.6	1000000	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
451	BASE STRENGTH	3.6	5	2.6	4.9	111001100	0
1120	AVERAGE SKID NUMBER (PER CONST JOB)	3.6	2	2.3	4.9	1100000000	0
383	SPECIFICATION ITEM USED FOR SUBBASE MATERIAL	3.6	3	2.9	4.2	10010	10000000
592	LONGITUDINAL STEEL TYPE	3.6	1	3.6	3.6	1000000000	0
556	TENSILE STRENGTH RANGES - CONCRETE	3.6	2	2.8	4.4	100000001	0
433	PERCENT OF CEMENT IN STABLIZED BASE	3.6	3	2.7	5.0	10010000000	1
885	TYPE OF CONCRETE PLACER	3.6	3	2.8	4.4	1000100000	100000000
118	MATERIAL TYPE FOR LANE EDGE LATERAL SUPPORT	3.6	2	2.2	5.0	10	100000
716	TYPE OF EACH MAINTENANCE EVENT	3.6	5	1.4	5.0	100101000100001	
656	PERCENT -200 SCREENINGS IN ACP MIX	3.6	4	1.2	5.0	1001010000	100000000
895	LENGTH OF HAUL	3.6	2	3.1	4.0	1	100000000
366	PLASTIC LIMIT OF SUBGRADE	3.6	5	2.4	4.9	111000000	110000000
746	AGGREGATE RATE - SEALS, PRIMES, OR CURING	3.6	3	2.7	4.1	1000100000001000000000	
959	COMPRESSION-TENSILE STRENGTH RATIO - LAYER	3.6	1	3.6	3.6	1	0
753	LEVEL-UP THICKNESS	3.6	2	3.5	3.6	10000000001	0
804	COST OF SHOULDERS/SQ YD	3.6	1	3.6	3.6	1000000	0
903	IDENTIFICATION OF SUPPLIER - BASE MATERIAL	3.6	9	2.0	4.7	1110100101	1010100
34	LEVEL OF SERVICE	3.6	5	2.7	4.0	10000000111000100	
718	TYPE OF EACH SURFACE MAINTENANCE	3.5	2	3.2	3.9	1010000	0
523	FINE AGGREGATE FACTOR	3.5	2	2.1	5.0	10001000000	0
889	TYPE OF ASPHALT COMPACTION EQUIPMENT	3.5	2	3.1	4.0	1001000000	0
514	TYPE OF MINERAL FILLER	3.5	2	3.0	4.1	1000010	0
961	NORMAL TOTAL PERCIPITATION FOR PERIOD DEC THRU MAY	3.5	2	3.3	3.8	10000100000000	
776	PRICE INDEX (INFLATION FACTOR) BY MONTH	3.5	4	2.5	4.5	100100001	1
1014	WHEEL LOAD	3.5	6	2.8	4.9	11100000001	10000010
1055	DIRECTIONAL TRAFFIC DISTRIBUTION (PERCENT)	3.5	8	2.7	5.0	1011100000001100010100	
791	INITIAL COST OF CONSTRUCTION	3.5	4	3.1	4.3	10000000010	110000000
847	SEAL COAT COST/LANE MILE	3.5	2	3.1	4.0	110000000	0
96	TYPE OF SHOULDER	3.5	16	1.7	4.8	1101011111101110111	

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE BLW	RANGE BHI	GROUPS	
1608	ANTICIPATED TRAFFIC GENERATION (IMMEDIATE)	3.5	2	3.1	4.0	100000000	10000000
476	DATE SURFACE COURSE PLACED	3.5	4	2.1	4.5	11000000001000010000	
705	LOAD TRANSFER FACTOR	3.5	2	2.2	4.9	100000000	100000000
816	SUBBASE COST/C.Y.	3.5	2	3.3	3.7	10000000	10000
563	INITIAL SURFACE TEXTURE INDEX NUMBER	3.5	1	3.5	3.5	1000000	0
1115	SKID NUMBER OF SURFACE - SEMI-ANNUALLY	3.5	1	3.5	3.5	0	10000000
1251	FREQUENCY OF REPAIR	3.5	2	3.1	4.0	0	10000010
545	TYPE VIBRATION	3.5	5	2.9	4.3	10010000101000000001	
737	DATE OF LAST SEAL COAT	3.5	5	2.4	4.9	100111	100000000
277	AVG PI OF EACH LAYER	3.5	1	3.5	3.5	0	10000000
176	PREDOMINANT GEOLOGIC FORMATION	3.5	9	2.3	4.6	1010111	11110000
1091	ANNUAL RIDING QUALITY OF PAVEMENT (MAYS ROAD METER)	3.5	14	2.3	5.0	10111111111000110011	
85	CULVERT WIDTHS	3.5	3	2.3	4.5	10000	10000100
663	ASPHALT GRADE	3.5	7	2.2	4.9	1011001000110010000000	
1158	LONGITUDINAL CRACKING (LENGTH)	3.5	3	2.1	4.4	101000000	1
393	SUBBASE STABILIZATION TYPE - SHOULDER	3.5	1	3.5	3.5	1000000000	0
1186	SPALLING (PERCENT OF CRACK)	3.5	3	2.4	4.2	100000000	1000010
747	ASPHALT TYPE - SEALS,PRIMES,CURING	3.5	3	3.2	3.9	10000110	0
711	QUALITY OF MAINTENANCE	3.5	1	3.5	3.5	0	100000000
843	COST OF OVERLAY/LANE MILE	3.5	4	2.7	4.0	110001000	10000
37	POPULATION OF AREA	3.5	1	3.5	3.5	10000000	0
846	COST OF SEAL COATS	3.5	1	3.5	3.5	0	10000
812	COST OF SUBBASE/LANE MILE	3.5	5	2.2	4.5	10101000	10000010
676	MAXIMUM MOLDED AGGREGATE DENSITY	3.5	1	3.5	3.5	10000000	0
153	VERTICAL ALIGNMENT	3.5	6	1.1	5.0	100010010	1100000 1
732	TYPE OF LAST MAJOR REHABILITATION	3.5	2	2.0	5.0	10	100000
435	BASE MATERIAL	3.5	17	2.5	5.0	10011111011111111101111	
102	UNPAVED SHOULDER WIDTH	3.5	2	2.9	4.1	10000100000	0
917	STATEMENT OF PROBLEMS DURING CONSTRUCTION	3.5	4	2.6	4.0	10001000100000100 0	

(Continued)

TABLE F-1. (Continued)

PAGE 23

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
673	DESIGN DENSITY - ACP	3.5	1	3.5	3.5	1000000000	0
76	RAMP LENGTH	3.5	1	3.5	3.5	100000	0
241	TYPE OF SURFACE TREATMENT EACH LAYER	3.5	1	3.5	3.5	1000000	0
855	TOTAL COST OF SPECIAL MAINTENANCE TO DATE	3.5	1	3.5	3.5	1	0
926	HUMIDITY DURING PAVING	3.5	2	3.0	4.0	1000000	1000000
968	TOTAL HOURS OF RAINFALL PER MONTH BY COUNTY	3.5	1	3.5	3.5	1000000000	0
998	TOTAL TRAFFIC TO DATE	3.5	1	3.5	3.5	0	10000
13	LINK OF LOG MILEPOST TO PLANS STATION NUMBER	3.5	1	3.5	3.5	0	1000000
527	MAXIMUM SIZE AGGREGATE - CONCRETE	3.5	1	3.5	3.5	1000000000	0
1244	VARIANCE IN SECTION FROM ORIGINAL CONDITION	3.5	1	3.5	3.5	1	0
1300	AVERAGE CRACK PATTERN - CRCP	3.5	1	3.5	3.5	10000000000	0
1301	AVERAGE CRACK WIDTH ON STANDARD TEMPERATURE BASE - CRCP	3.5	1	3.5	3.5	10000000000	0
744	AGGREGATE TYPE - SEALS, PRIMES, CURING	3.5	5	2.7	4.9	1001000001101000000000	
1013	TRAFFIC LOAD	3.5	13	2.0	4.9	10111111110110101 0	
925	MONTHLY RAINFALL DURING CONSTRUCTION	3.5	2	3.1	3.9	1000001	0
104	FOUNDATION COURSE WIDTH - SHOULDER	3.5	1	3.5	3.5	1000000000	0
97	ORIGINAL SHOULDER DEPTH - REVISED PVMT	3.5	1	3.5	3.5	1000000000	0
1067	DATE OF INSPECTION	3.5	1	3.5	3.5	0	100000
1074	CONDITION OF SURFACE	3.5	1	3.5	3.5	0	1000000
532	CONCRETE WATER FACTOR	3.5	3	2.0	4.7	10000000110	0
624	STEEL PLACEMENT (HAND OR MACHINE)	3.5	4	2.3	4.7	1001000010	100000000
162	LOAD IMPACT FEATURES OF ALIGNMENT	3.5	3	2.5	4.1	0	110100000
745	AGGREGATE GRADE - SEALS, PRIMES, CURING	3.5	3	2.5	4.9	1000000001001000000000	
569	TYPE OF CONTRACTION JOINT - CONCRETE PAVEMENT	3.5	1	3.5	3.5	10	0
582	CLASS OF JOINT SEALING MATL - CONC PVMT	3.5	3	3.3	3.7	1001000010	0
821	COST OF BASE PREPARATION/LANE MILE	3.5	9	2.9	4.3	110011000	10111010
1215	FREQUENCY OF FLUSHING	3.5	2	2.1	4.9	1000000000	100000000
501	TYPE OF CEMENT - CONCRETE PAVEMENT	3.5	9	2.4	5.0	1111000010	100010011
894	FREQUENCY OF EQUIPMENT BREAKDOWNS	3.5	2	3.1	3.9	10	100000000

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
1043	YEARLY ADT	3.5	2	3.0	3.9	10	1
908	IDENTIFICATION OF SUPPLIER - AGGREGATE (COARSE)	3.5	6	2.8	4.3	1011000010	101000000
356	DENSE DENSITY (DD) - SUBGRADE	3.4	4	3.0	4.5	1110000000	1
103	ORIGINAL SHOULDER WIDTHS - REVISED PVMT	3.4	1	3.4	3.4	1000000000	0
518	SOURCE OF WATER USED IN CONCRETE PAVEMENT	3.4	3	2.3	5.0	1001000010	0
564	TYPE OF JOINT - CONCRETE PAVEMENT	3.4	9	1.0	4.8	10111011000	101010000
844	COST OF OVERLAY PER SQ. YD.	3.4	3	2.6	4.1	1100000001	0
1305	MAXIMUM SIZE AGGREGATE - ASPH CONC	3.4	1	3.4	3.4	1000000000	0
1306	PERCENT +4 MESH AGGREGATE - ASPH CONC	3.4	1	3.4	3.4	1000000000	0
1307	PERCENT +80 MESH AGGREGATE - ASPH CONC	3.4	1	3.4	3.4	1000000000	0
1308	PERCENT +200 MESH AGGREGATE - ASPH CONC	3.4	1	3.4	3.4	1000000000	0
1268	NATURAL SOIL PROFILE P.I.,DEPTH, AND LOCATION	3.4	1	3.4	3.4	10000000000	0
357	SUBGRADE SOIL STRENGTH (IN USUAL OR WEAKEST CONDITION)	3.4	3	3.2	3.7	101001000	0
940	MAXIMUM TEMPERATURE DIFFERENTIAL - DURING WINTER	3.4	2	3.4	3.4		01001000000
525	HARDNESS OF AGGREGATE FOR CONC PVT	3.4	2	2.8	4.0	10000000	1
978	HUMIDITY RANGE	3.4	1	3.4	3.4	100000	0
1100	SEMI-ANNUAL SERVICEABILITY INDEX RATING	3.4	1	3.4	3.4		01000000000
1011	AVERAGE WEIGHT OF TRUCK TRAFFIC	3.4	2	3.0	3.8	0	1100
615	DOWEL SPACING	3.4	3	2.0	4.7	11001000000	0
1294	PERCENT ASPHALT IN ACP	3.4	1	3.4	3.4	100000000	0
1071	CONDITION OF STRIPING	3.4	1	3.4	3.4	1000000000	0
1098	SERVICEABILITY INDEX - BI ANNUALLY	3.4	1	3.4	3.4	100000000	0
632	LIFE SHOT AND ROCK PER SHOT	3.4	1	3.4	3.4	0	1
440	MAXIMUM SIZE AGGREGATE - BASE	3.4	1	3.4	3.4	1000000000	0
456	BASE STIFFNESS COEFFICIENT - SHOULDER	3.4	1	3.4	3.4	100000000	0
1047	PERCENT GROWTH ADT (YEARLY)	3.4	1	3.4	3.4	0	10000
194	DEPTH OF DITCH	3.4	8	1.6	4.7	1111010100	100100000
444	RATIO OF MATERIALS FOR BASE	3.4	2	2.6	4.2	10000000	10000
90	BRIDGE WIDTH	3.4	5	2.4	4.5	100100000	110001000

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
498	CONCRETE RATE OF PLACEMENT	3.4	2	3.0	3.7	1000000000 100000000
126	TYPE OF SECTION (CUT,FILL, OR GRADE)	3.4	7	2.6	4.2	1001001001101000010
82	LOCATION OF CURBS	3.4	13	1.2	5.0	11110110000 111110101
1149	AMOUNT OF CRACKING	3.4	3	3.0	3.8	1000000000 1000010
445	METHOD OF COMPACTION - BASE	3.4	2	3.0	3.8	10010000000 0
317	DENSITY - EMBANKMENT	3.4	3	2.2	4.8	10100000000 100
86	HYDRAULIC DESIGN FREQUENCY (BY CULVERTS AND BRIDGES)	3.4	2	2.2	4.5	100000000 10000000
170	CROSSFALL OF ROAD	3.4	1	3.4	3.4	100 0
30	CLASSIFICATION OF HIGHWAY (FAI,FAP,FAS,ETC)	3.4	11	1.0	4.7	11111110001 101100
966	MONTHLY AVERAGE RAINFALL	3.4	7	3.0	3.8	100000010 100111010
591	TYPE OF STEEL	3.4	5	1.4	4.0	10011000010 1000
202	DITCH HYDRAULICS	3.3	2	2.1	4.6	10100000000 0
134	GEOMETRIC DESCRIPTION OF CROSS SECTION	3.3	2	2.8	3.9	0 10100000
496	FORMED OR FORMLESS PLACEMENT - CONCRETE PVMT	3.3	4	1.8	4.8	110 100000100
965	SEASONAL AVERAGE RAINFALL	3.3	4	2.1	4.0	110000 10100000
587	DEPTH OF REINFORCEMENT	3.3	2	2.8	3.8	110000000 0
80	MEDIAN WIDTH	3.3	10	2.6	5.0	1010110010110011010 0
148	SUPER OF CURVES	3.3	2	1.9	4.7	100000 100000000
346	WIDTH OF SUBGRADE STABILIZATION	3.3	4	2.8	4.5	11000000001 1000000
475	SPECIFICATION ITEM USED FOR SURFACE TREATMENT	3.3	2	3.1	3.5	1000000010 0
761	TRAFFIC MODEL USED EACH OVERLAY	3.3	1	3.3	3.3	10000000 0
365	SUBGRADE BEARING VALUE (WESTERGAARD K)	3.3	2	2.8	3.8	1000100 0
398	MAXIMUM SIZE AGGREGATE - SUBBASE	3.3	1	3.3	3.3	1000000000 0
119	STAGE CONSTRUCTION INFORMATION	3.3	7	2.1	5.0	1001111110000010
803	COST OF SHOULDERS/MILE	3.3	1	3.3	3.3	0 100000
319	PERCENT OF OPTIMUM MOISTURE IN EMBANKMENT WHEN BUILT	3.3	4	2.6	4.1	111100000 0
1261	NUMBER OF ACCIDENTS PER YEAR LAST FIVE YEARS	3.3	2	2.9	3.7	10000000001000000000
766	AVERAGE TIME DELAY PER CAR	3.3	1	3.3	3.3	0 10000000
898	AVAILABILITY OF MATERIALS	3.3	7	2.6	4.0	11000001001111000000000

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
113	TYPE STABILIZING AGENT - EACH SHOULDER LAYER	3.3	1	3.3	3.3	01000000000
865	ANNUAL MAINT COST OF MEDIAN/MILE	3.3	1	3.3	3.3	10 0
912	IDENTIFICATION OF SUPPLLIER - MATERIALS	3.3	2	2.7	3.9	1000 10000
913	NUMBER OF INTERRUPTIONS	3.3	1	3.3	3.3	1000000 0
914	REASON FOR INTERRRUPTIONS	3.3	1	3.3	3.3	1000000 0
536	CONCRETE MIXING METHOD (DUAL DRUM OR CENTRAL PLANT)	3.3	2	3.0	3.6	1001000000 0
242	THICKNESS OF SURFACE TREATMENT EACH LAYER	3.3	1	3.3	3.3	1000000 0
19	LOCATION OF CROSSOVERS	3.3	1	3.3	3.3	0 10000000
1299	RAINFALL HISTORY	3.3	1	3.3	3.3	10000000000 0
350	COMPACTION EFFORT ON SUBGRADE	3.3	8	2.2	4.9	10011101000 100001010
864	COST OF CONC PVT REPAIRS PER LANE MILE	3.3	2	2.9	3.7	10000000 100000
261	TYPE OF FLEXURAL STRENGTH TEST	3.3	1	3.3	3.3	1000000000 0
466	PERCENT MOISTURE OF BASE AT TIME OF LAYING	3.3	1	3.3	3.3	0 1000000
964	ANNUAL AVERAGE RAINFALL	3.3	21	1.6	4.3	111111111111111111111
355	LOOSE DENSITY (DL) - SUBGRADE	3.3	2	3.2	3.4	10010000000 0
1003	TEN YEAR PROJECTED ADT	3.3	3	2.3	4.5	10000010000 100
832	COST OF ASPHALT FOR ACP	3.3	1	3.3	3.3	1 0
835	COST OF AGGREGATE FOR ACP	3.3	1	3.3	3.3	1 0
292	LAYER SOIL CONSTANTS	3.3	4	1.4	4.2	101001000010000
557	CONCRETE COMPRESSIVE STRENGTH	3.3	4	2.2	5.0	111000000 1
426	BASE TREATMENT	3.3	6	2.3	4.3	1010100001010001000
904	IDENTIFICATION OF SUPPLIER - SUBBASE MATERIAL	3.3	2	3.1	3.5	1000000000 1000000
921	GENERAL WEATHER CONDITION AT TIME OF PLACEMENT	3.3	6	2.4	4.0	111010000 100000010
756	DATE OF LAST OVERLAY	3.3	3	2.5	4.0	101 100000000
757	MAXIMUM GRADE	3.3	7	2.6	4.7	1001000010111110000000
322	ACTUAL DENSITY (DA) - BORROW MATERIAL	3.3	1	3.3	3.3	10000000 0
1349	DATE OF PERCENT TRUCKS DATA	3.3	1	3.3	3.3	1000000000 0
1242	EXISTING MOISTURE CONTENT OF SUBGRADE -SAMPLE- EA 6 MOS	3.3	2	1.6	4.9	100000010 0
450	CURING OF BASE	3.3	3	2.4	4.4	1001000 1

(Continued)

TABLE F-1. (Continued)

PAGE 27

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
756	USUAL GRADE	3.3	6	2.2	4.0	100001011100010000
62	NUMBER OF LANES - INITIALLY	3.3	2	2.8	3.7	1010000000 0
1089	ANNUAL PAVEMENT PROFILE	3.2	3	2.1	4.3	1000 110000
792	COST PER LANE MILE OF CONSTRUCTION	3.2	14	1.8	4.9	101101111001011011110
758	OVERLAY MATERIAL	3.2	1	3.2	3.2	10000000 0
1028	ESTIMATE OF ILLEGAL OVERWEIGHT APPLICATIONS PER YR	3.2	1	3.2	3.2	0 100000
927	AVG WIND VELOCITY DURING PAVING	3.2	3	1.8	4.0	101000000 1000000
40	STATEMENT OF ROAD USER BENEFITS	3.2	1	3.2	3.2	0 10000000
99	INSIDE SHOULDER WIDTH	3.2	8	2.4	4.1	110010100001100100100
570	CONTRACTION JOINT SPACING - CONCRETE PAVEMENT	3.2	4	2.6	4.1	1110000010 0
504	TYPE OF CONCRETE MIX ADDITIVES	3.2	4	2.3	3.8	1100000010 100000000
594	GRADE OF LONGITUDINAL STEEL	3.2	1	3.2	3.2	1000000000 0
754	OVERLAY NUMBER	3.2	5	2.5	4.1	11000001 100010000
428	TYPE OF BASE STABILIZATION - SHOULDER	3.2	2	2.9	3.6	1000000000 100000
752	HORIZONTAL ALIGNMENT	3.2	5	1.5	4.6	100010010 11000000
98	SHOULDER WIDTH	3.2	21	1.6	4.6	111111111111111111111
777	PREVIOUS CORE HOLES IN VICINITY	3.2	2	2.9	3.5	11000000000
810	COST OF SUBGRADE PREPARATION/SQ. YD.	3.2	5	1.9	4.4	1000011000110000
931	AREA TEMPERATURE CONSTANT	3.2	3	1.8	4.8	100001 100000000
773	SHOULDER SLOPE	3.2	10	2.2	4.7	101111001011100000001
605	SPACING OF LONGITUDINAL REINFORCING STEEL	3.2	2	2.9	3.5	1000000001 0
939	ANNUAL TEMPERATURE DIFFERENTIAL	3.2	5	1.6	4.0	110000111000000000
604	REBAR SPACING - CRCP	3.2	7	2.4	4.0	101110000001100100000
423	CORE THICKNESS OF BASE	3.2	1	3.2	3.2	0 1000000
970	MAXIMUM ANNUAL RAINFALL	3.2	2	2.5	3.9	0 1000010
971	MINIMUM ANNUAL RAINFALL	3.2	2	2.5	3.9	0 1000010
944	MINIMUM TEMPERATURE	3.2	10	2.3	5.0	101110110 1100110
815	COST OF SUBBASE/SQ YD	3.2	1	3.2	3.2	1000000 0
408	MAXIMUM PLASTICITY INDEX - SUBBASE	3.2	1	3.2	3.2	10000 0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
1262	LOCATION AND DESCRIPTION EACH ACCIDENT/YR-LAST 5 YRS	3.2	1	3.2	3.2	01000000000	
21	LOCATIONS EXPOSED TO TRAFFIC BRAKING	3.2	1	3.2	3.2	100	0
191	LOCATION OF DITCHES	3.2	2	2.5	3.9	10100000000	0
151	NUMBER OF VERTICAL CURVES OVER 2 DEGREES	3.2	1	3.2	3.2	100000	0
145	CROWN WIDTH	3.2	8	.6	5.0	101110111	10
201	FREE WATER STANDING IN DITCHES	3.2	1	3.2	3.2	10000000	0
150	NUMBER OF HORIZONTAL CURVES OVER 1 DEGREE	3.2	1	3.2	3.2	100000	0
74	LOCATION OF RAMPS	3.2	3	1.9	4.3	10100000000	10000000
808	COST OF STABILIZED SUBGRADE/LANE MILE	3.2	6	2.2	4.1	100110100	1000001
192	DISTANCE TO DITCH FROM SUBGRADE CROWN	3.2	1	3.2	3.2	100000	0
83	CURB HEIGHT	3.2	2	3.0	3.4	10000000	100000000
614	DOWEL BAR SIZE	3.2	4	2.0	4.1	11001000000	100000000
138	PAVEMENT WIDTH	3.2	7	2.4	4.1	10000010101	110010
147	DEGREE OF CURVES	3.2	8	1.1	4.7	1101101101000010000	
620	BOND AREA OF LONGITUDINAL STEEL - CRCP	3.2	1	3.2	3.2	100000000	0
39	ANTICIPATED FUTURE POPULATION OF AREA (DIST EST)	3.2	1	3.2	3.2	10000000	0
159	PROFILE GRADE LINE	3.2	4	1.6	3.8	1010000010	100000000
1285	BASE COMPACTION RATIO (TEX-114E)	3.2	1	3.2	3.2	10000000000	0
1237	PERCENT LANE MI OF PVMT WITH EDGE FAILURES	3.2	1	3.2	3.2	01000000000	
648	AFFINITY OF SURFACE AGGREGATES FOR VARIOUS ASPHALTS	3.2	1	3.2	3.2	100	0
602	LONGITUDINAL BAR SIZE - CONCRETE PAVEMENT	3.2	1	3.2	3.2	1000000000	0
779	DIST WIDE LOW BID - LANE MI - 1 INCH ACP - 10 INCH FB	3.2	1	3.2	3.2	0	100
337	SUBGRADE SOIL IDENTIFICATION - FHWA CLASSIFICATION	3.2	2	2.6	3.7	0	110000
682	COHESIOMETER VALUE OF ACP	3.2	5	2.0	4.1	1010100011000000000	
228	LAYER GRADATION	3.2	3	1.9	4.5	100001100	0
143	PAVEMENT MICRO TEXTURE	3.2	1	3.2	3.2	0	10000000
763	PLANNED FUTURE OVERLAYS - TIME,NUMBER,TYPE	3.2	4	1.4	4.1	11	1100000
853	ANNUAL ROUTINE MAINTENANCE COST - PER MI	3.1	2	2.8	3.5	100000	10000000
461	MAXIMUM PLASTICITY INDEX - BASE	3.1	2	3.1	3.2	10000010000	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
845	COST OF OVERLAY PER COMPACTED CUBIC YARD	3.1	1	3.1	3.1	10000000	0
1112	SHOULDERS (STABILIZED OR NATURAL)	3.1	1	3.1	3.1	0	100000
979	ANNUAL AVERAGE SNOWFALL	3.1	2	2.4	3.9	101	0
519	CONCRETE AGGREGATE TYPE	3.1	2	2.5	3.8	1000000000	1
692	PENETRATION TEST RESULTS BITUMINOUS MATTERS	3.1	1	3.1	3.1	1000000	0
856	ANNUAL MAINT COST OF TRAFFIC LANES SUBGRADE/LANE MILE	3.1	3	2.1	5.0	10010	1000000
412	ABSORPTION PERCENT OF SUBBASE	3.1	1	3.1	3.1	0	10000
406	MATERIAL STRENGTH - R-VALUE	3.1	1	3.1	3.1	1000000000	0
78	TYPE OF MEDIAN (RAISED,FLUSH,DEPRESSED)	3.1	12	1.8	4.4	111000100101111010101	
227	RATE OF MATERIAL APPLICATION - LAYER	3.1	2	2.7	3.6	100000000	10000000
449	WET BALL MILL VALUE OF BASE MATERIAL	3.1	2	3.0	3.3	10010000000	0
314	ELEVATION OF PAVEMENT IN RELATION TO NATURAL GROUND	3.1	5	1.1	4.0	10010001	10001000
1149	MAXIMUM VALUE FOR HORIZONTAL CURVES	3.1	3	2.2	4.5	10000000000	110000000
611	CONTINUOUS STEEL SIZE	3.1	1	3.1	3.1	1000000	0
612	CONTINUOUS STEEL SPACING	3.1	1	3.1	3.1	1000000	0
1283	PERCENT OF DENSITY REQUIREMENT FOR BASE COURSES	3.1	1	3.1	3.1	10000000000	0
1009	ANTICIPATED TRAFFIC GENERATION (FUTURE)	3.1	2	2.6	3.7	100000000	1000000
439	SIEVE ANALYSIS OF BASE MATERIAL	3.1	2	2.5	3.7	10010000000	0
1115	PERCENT STABILIZING AGENT - EACH SHOULDER LAYER	3.1	1	3.1	3.1		01000000000
928	PREVAILING WEATHER CONDITIONS	3.1	3	1.9	4.4	1001000000	10000000
907	IDENTIFICATION OF SUPPLIER - AGGREGATE	3.1	12	.7	4.7	11110111011100100100	
340	DEPTH OF SUBGRADE	3.1	5	1.9	4.8	10010010010000000010	
1124	DESCRIPTION OF ANY WIDENING OF ORIGINAL PVMT	3.1	1	3.1	3.1	100	0
694	PENETRATION MATERIALS	3.1	1	3.1	3.1	100000	0
484	DENSITY OF SURFACE	3.1	2	2.8	3.4	100000000	1
1190	STORM SEWER SYSTEM	3.1	1	3.1	3.1	100000	0
943	MAXIMUM TEMPERATURE	3.1	8	2.2	4.0	101110100	1000110
81	MEDIAN SURFACE (SODDED OR PAVED)	3.1	1	3.1	3.1	10000000	0
362	SUBGRADE MODULUS	3.1	2	2.9	3.3	1010	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
299	CAPILLARY POTENTIAL EXHIBITED BY LAYERS	3.1	4	2.1	4.3	110	1010000
562	AVERAGE TEXTURE DEPTH	3.1	2	1.9	4.3	1010	0
172	CUT SECTION SLOPES	3.1	1	3.1	3.1	100000	0
171	FILL SECTION SLOPES	3.1	1	3.1	3.1	100000	0
935	MONTHLY AVERAGE TEMPERATURE	3.1	6	2.2	3.9	1100001000	100001010
1211	AMOUNT OF PATCHING	3.1	2	2.8	3.3	1000000000	1000000
166	TRANSVERSE SLOPE	3.1	2	1.6	4.5	100000	100000000
397	GRADE OF SUBBASE MATERIAL	3.0	2	2.5	3.6	1000000000	10000
784	AMOUNT OF CONTRACT (DOLLARS)	3.0	3	2.7	3.5	10001000000	1000
1110	SKID RESISTANCE PROFILE EACH TWO YEARS	3.0	2	2.4	3.7	110000000	0
870	DATE OF MATERIALS COSTS - MAINT	3.0	1	3.0	3.0	1000000000	0
400	AGGREGATE - PERCENT PASSING NUM 200 SIEVE - SUBBASE	3.0	1	3.0	3.0	1000000000	0
399	AGGREGATE - PERCENT PASSING NUM 4 SIEVE - SUBBASE	3.0	1	3.0	3.0	1000000000	0
312	EMBANKMENT SOIL TYPE	3.0	2	2.5	3.6	100001000	0
871	MATERIAL COSTS-MAINTENANCE-PER CONST JOB	3.0	1	3.0	3.0	1000000000	0
653	TYPE OF AGGREGATE USED FOR SURFACE TREATMENT	3.0	3	2.9	3.3	11000000000	1000000
797	MATERIAL-IN-PLACE-COST - CONSTRUCTION	3.0	3	2.2	4.3	1001000100000	
902	IDENTIFICATION OF SUPPLIER - ASPHALT	3.0	8	.7	4.4	1110010111	1000000
193	DITCH GRADE	3.0	2	2.4	3.7	10000100000	0
1357	DATE OF LANE DISTRIBUTION	3.0	1	3.0	3.0	1000000000	0
222	METHOD OF MIXING - STABILIZATION	3.0	1	3.0	3.0	1000000	0
778	STATEWIDE LOW BID - LANE MI - 1 INCH ACP - 10 INCH FB	3.0	1	3.0	3.0	0	100
955	DEPTH TO FROST LINE	3.0	3	1.6	3.9	100100000	10000000
708	ESTIMATED MAINTENANCE FREE LIFE (YEARS)	3.0	1	3.0	3.0	01000000000	
1250	AMT OF SOIL BINDER IN BASE - 5 YR PERIODS	3.0	1	3.0	3.0	100000	0
606	SPACING OF TRANSVERSE REINFORCING STEEL	3.0	2	2.5	3.5	1000000001	0
765	NUMBER OF CARS DELAYED IN OVERLAY ZONE	3.0	1	3.0	3.0	0	10000000
308	COMPACTED DENSTIY OF FOUNDATION COURSE	3.0	1	3.0	3.0	1000000000	0
309	STRENGTH COEFFICIENT OF FOUNDATION COURSE	3.0	1	3.0	3.0	1000	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
95	DATE OF SUBSEQUENT SHOULDER WORK	3.0	1	3.0	3.0	1000	0
164	MINIMUM HORIZONTAL CLEARANCE	3.0	3	2.1	3.5	01100000100	
597	YIELD STRENGTH TRANSVERSE STEEL	3.0	1	3.0	3.0	1000000000	0
919	TEST REPORTS ON MATERIALS USED FOR CONSTRUCTION	3.0	1	3.0	3.0	0	1000
622	COVER OF STEEL	3.0	1	3.0	3.0	1000000	0
240	TYPE OF BONDING MATERIAL - LAYER	3.0	1	3.0	3.0	0	10000
243	METHOD OF COMPACTION - LAYER	3.0	1	3.0	3.0	10	0
786	FUTURE PROGRAM FUNDS OBLIGATED TO OVERRUNS	3.0	1	3.0	3.0	0	1000
1052	PROJECTED FIVE YEAR PERCENT ADT TRUCKS	3.0	1	3.0	3.0	01000000000	
1069	CONDITION OF SIGNS	3.0	1	3.0	3.0	1000000000	0
139	DESIGN CONFIDENCE LEVEL	3.0	1	3.0	3.0	0	100000000
1107	MILEPOINT LOCATOR FOR SKID RESISTANCE MEASUREMENT	3.0	1	3.0	3.0	0	1
89	TYPE OF BRIDGES ON JOB	3.0	2	3.0	3.0	100000	1000
608	WERE RE-BAR SUPPORTS USED	3.0	1	3.0	3.0	0	1000000
607	LAP LENGTH	3.0	1	3.0	3.0	1000000000	0
595	GRADE OF TRANSVERSE STEEL	3.0	1	3.0	3.0	1000000000	0
785	PROJECT OVERRUNS AND METHOD OF FINANCING	3.0	1	3.0	3.0	0	1000
1298	TEMPERATURE HISTORY	3.0	1	3.0	3.0	10000000000	0
1302	SEASONAL TRAFFIC DISTRIBUTION	3.0	1	3.0	3.0	10000000000	0
1303	STRESS SENSITIVITY OF CLAY LAYERS	3.0	1	3.0	3.0	10000000000	0
1123	SKID NUMBER AFTER EACH SEAL COAT	3.0	1	3.0	3.0	10000000	0
1063	AVERAGE SPEED OF TRAFFIC	3.0	11	1.6	4.0	10101111100	11010100
313	THICKNESS, EMBANKMENT OR FILL HEIGHT - SUBGRADE	3.0	1	3.0	3.0	10000000	0
725	MATERIAL TYPE OF EACH REHABILITATION LAYER	3.0	2	3.0	3.0	10100000	0
817	COST OF BASE/LANE MILE -TRAFFIC LANE	3.0	2	2.4	3.5	10	1000
55	NUMBER OF STOP CONDITIONS	3.0	3	2.8	3.1	100000000	100010000
443	PERCENT OF 200 MATL IN BASE	3.0	3	2.5	3.5	1000000000	100010000
905	IDENTIFICATION OF SUPPLIER - STABILIZATION AGENT	3.0	3	2.4	4.0	111000000000	
1122	SKID NUMBER AFTER EACH OVERLAY	3.0	1	3.0	3.0	10000000	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE LOW	RANGE HI	GROUPS
327	PLASTIC LIMIT OF BORROW MATERIAL	3.0	1	3.0	3.0	10000000 0
783	TOTAL PROJECT COST	3.0	1	3.0	3.0	0 1000
733	DESCRIPTION OF DISTRESS REQUIRING REHABILITATION	3.0	1	3.0	3.0	0 10
506	BRAND OF AIR ENTRAINING AGENT USED IN CONCRETE PVMT	3.0	3	1.5	5.0	11000010 0
1287	LINEAR SHRINKAGE OF BASE MATERIAL	3.0	1	3.0	3.0	10000000000 0
763	MINIMUM VERTICAL CLEARANCE HEIGHT	3.0	5	1.8	4.4	10100000000 110000100
57	CLIMBING LANE WIDTH	3.0	2	2.2	3.8	0 100100000
291	PERMEABILITY - LAYER	3.0	3	2.4	3.8	1000001001000000000
675	ACP IN-PLACE DENSITY	3.0	2	2.9	3.0	10000000001000000000
1525	RECORD OF OVERSIZE PERMITS	3.0	2	2.6	3.3	10000000000 100000
798	COST OF MATERIALS - CONSTRUCTION	2.9	3	2.3	3.8	1000000011000000000
601	REBAR SIZE - CRCP	2.9	5	2.4	3.5	10101000000 100100000
666	TYPE OF EXPANSION JOINT - CONCRETE PAVEMENT	2.9	2	2.5	3.4	1000010 0
668	RATE OF ASPHALT FOR PENETRATION PAVEMENTS	2.9	1	2.9	2.9	1000 0
581	TYPE OF JOINT SEALER - CONCRETE PAVEMENT	2.9	4	1.6	4.8	100000101 100
795	DEPTH OF DITCH BELOW SUBGRADE (INSIDE)	2.9	1	2.9	2.9	0 100000
413	ERODABILITY FACTOR/SUBBASE	2.9	2	2.8	3.1	100000000 10
467	PERCENT OF OPTIMUM MOISTURE IN FLEX BASE WHEN BUILT	2.9	4	2.4	3.3	11100000 1
953	FREEZING INDEX PER YEAR BY COUNTY	2.9	3	2.3	4.0	11001000000 0
338	UNIFORMITY OF SUBGRADE	2.9	1	2.9	2.9	1 0
121	TYPE OF LAST CONSTRUCTION	2.9	1	2.9	2.9	01000000000
773	TYPE OF MATERIAL TO REPAIR SPALLED JOINTS	2.9	1	2.9	2.9	10 0
203	GUTTER WIDTH	2.9	5	1.9	3.9	10010010000 100010000
670	AGGREGATE RATE FOR PENETRATION PAVEMENTS	2.9	1	2.9	2.9	1000 0
1187	PERCENT LANE MI OF PVMT WITH SPALLING JOINTS	2.9	1	2.9	2.9	10000000 0
369	REDUCTION IN PLASTICITY INDEX BY STABILIZATION	2.9	1	2.9	2.9	01000000000
474	TYPE OF MEMBRANE BETWEEN BASE MATL AND PAVEMENT	2.9	5	1.2	4.4	1000001110010000000
906	IDENTIFICATION OF SUPPLIER - CEMENT USED IN CONC PVT	2.9	1	2.9	2.9	1000000 0
886	TYPE OF CONCRETE HAULING EQUIPMENT	2.9	1	2.9	2.9	0 100000000

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
439	TYPE OF ASPHALT MATL USED FOR PRIME COAT	2.9	3	1.9	3.8	1000010	1000
754	HORIZONTAL CURVATURE	2.9	1	2.9	2.9	0	100000000
335	SHRINKAGE FACTOR	2.9	2	1.7	4.1	110000000	0
67	LANE WIDTH - INITIALLY	2.9	2	2.6	3.1	1010000000	0
709	ESTIMATED MAJOR MAINTENANCE FREE LIFE (YEARS)	2.9	1	2.9	2.9		01000000000
529	AGGREGATE PERCENT PASSING NUM 100 SIEVE - CONCRETE	2.9	1	2.9	2.9	1000000000	0
881	TYPE OF PLANT	2.9	1	2.9	2.9	0	100000000
746	USUAL DISTANCE FROM CROWN TO DITCH	2.9	1	2.9	2.9	1000000	0
900	AVAILABILITY OF AGGREGATES	2.9	1	2.9	2.9	0	100
17	LOCATION OF ALL PVMT CONSTRUCTION JOINTS	2.8	2	2.7	3.0	1000000000	1
716	SHOULDER STABILITY	2.8	1	2.8	2.8	0	1
568	TYPE OF MATERIAL USED IN EXPANSION JOINTS	2.8	1	2.8	2.8	10	0
901	AVAILABILITY OF CEMENT	2.8	1	2.8	2.8	0	100
92	ARMOR JOINTS (BRIDGE ABUTMENTS) - TYPE	2.8	6	2.1	4.0	10000000001111000001	
735	NUMBER OF SEAL COATS	2.8	5	2.3	3.9	101000010	10001
714	TYPE OF SUBGRADE STABILIZATION - SHOULDERS	2.8	1	2.8	2.8	0	100000
329	SPECIFIC GRAVITY OF BORROW MATERIAL	2.8	1	2.8	2.8	10000000	0
899	AVAILABILITY OF ASPHALT	2.8	1	2.8	2.8	0	100
851	ESTIMATED ANNUAL MAINTENANCE COST	2.8	3	2.1	4.0	10100000000	10000
948	LOWEST DAILY TEMPERATURE PER MONTH BY COUNTY	2.8	1	2.8	2.8	1000000000	0
947	HIGHEST DAILY TEMPERATURE PER MONTH BY COUNTY	2.8	1	2.8	2.8	1000000000	0
54	CONTROL OF ACCESS	2.8	3	.7	3.9	10000	10000100
663	CHEMICAL SOUNDNESS VALUE OF SURFACE AGGREGATES	2.8	1	2.8	2.8	100	0
579	WIDTH OF SAWED JOINT	2.8	1	2.8	2.8	10	0
728	DEPTH OF ROADWAY EXCAVATION	2.8	1	2.8	2.8	1000	0
657	PERCENT +10 MATERIAL IN ACP MIX	2.8	3	1.2	4.0	1001010000	0
341	SUBGRADE WIDTH	2.8	4	2.1	3.1	10000001000110000000	
809	COST OF SUBGRADE PREPARATION/LANE MILE	2.8	20	1.8	4.6	11111111111111101111	
689	DUCTILITY TEST RESULTS BITUMINOUS MATTERS	2.8	1	2.8	2.8	1000000	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
200	SLOPE RATIO OF SIDE ROAD DITCH	2.8	5	.7	4.9	10110010000 100000000
780	SALVAGE VALUE OF PAVEMENT - LAYER	2.8	5	1.8	3.9	1000000011000010100
434	RATE OF APPLICATION FOR BASE MATERIAL STABILIZER	2.8	3	2.1	3.9	10000000001 1000000
946	AVERAGE WINTERTIME TEMPERATURE	2.8	11	1.1	3.6	1110101110111010 0
590	PERCENT TRANSVERSE STEEL IN EACH LAYER	2.8	3	2.0	3.3	1001010000 0
446	COMPACTION EFFORT ON BASE MATERIAL	2.8	7	2.1	3.2	10111100000 11
603	TRANSVERSE BAR SIZE - CONCRETE PAVEMENT	2.8	1	2.8	2.8	1000000000 0
1239	PERCENT LANE MI OF PVMT WITH POT HOLES	2.8	1	2.8	2.8	10000000 0
741	WIDTH OF SEALS, PRIMES, CURING	2.8	1	2.8	2.8	10000000000 0
1065	TIRE PRESSURE	2.7	1	2.7	2.7	10000000000 0
175	TOPOGRAPHY	2.7	13	1.0	5.0	11111111010111 0010000
1196	DEPTH OF RUTTING AT INTERSECTIONS	2.7	1	2.7	2.7	0 1000000
1090	VARIANCE IN PROFILE FROM ORIGINAL	2.7	1	2.7	2.7	1 0
1295	APPROXIMATE THICKNESS OF NATURAL UNDERLYING MATERIAL	2.7	1	2.7	2.7	0 1000000
503	CEMENT QUANTITY	2.7	3	1.1	3.7	11000000000 100000
969	DIFFERENCE BETWEEN MAX AND MIN MONTHLY RAINFALL	2.7	2	1.8	3.6	0 100001000
789	BID PRICE FOR EACH LAYER - PER S.Y.	2.7	6	2.0	3.4	1101010000 1000010000
977	AVERAGE HUMIDITY	2.7	4	2.4	3.0	11000010 10000
487	HARDNESS OF ASPHALT	2.7	1	2.7	2.7	100000000 0
407	SUBBASE E VALUE	2.7	1	2.7	2.7	1000000000 0
1171	PERCENT LANE MI OF PVMT WITH SLIPPAGE CRACKING	2.7	1	2.7	2.7	10000000 0
807	COST OF RAW SUBGRADE/LANE MILE	2.7	3	2.0	4.1	100100000 1000000
936	AVERAGE DAILY TEMPERATURE PER MONTH BY COUNTY	2.7	1	2.7	2.7	1000000000 0
1088	SHOULDER CONDITION - VEGETATION	2.7	1	2.7	2.7	1000000000 0
230	NOMINAL MAX SIZE OF AGGREGATE - LAYER	2.7	1	2.7	2.7	1000000 0
600	MODULUS OF ELASTICITY FOR STEEL REINFORCEMENT	2.7	1	2.7	2.7	100000000 0
1142	SURFACE CURVATURE INDEX - BASE	2.7	1	2.7	2.7	0 1000000
174	SAFETY SLOPE (FT.)	2.7	1	2.7	2.7	0 100000000
178	HYDROMETER ANALYSIS OF SUBGRADE	2.7	1	2.7	2.7	10000000 0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
867	COST OF ROADSIDE MAINT/MILE	2.7	3	2.3	3.1	1000000001	1000
1267	NATURAL SOIL PROFILE L.L.,DEPTH, AND LOCATION	2.7	1	2.7	2.7	10000000000	0
1269	NATURAL SOIL PROFILE L.S.,DEPTH, AND LOCATION	2.7	1	2.7	2.7	10000000000	0
404	SOIL SUPPORT VALUE - CBR	2.7	1	2.7	2.7	1	0
32	RIGHT OF WAY WIDTH	2.7	10	1.1	4.2	111111010	100010100
882	CONSTRUCTION EQUIPMENT USED	2.7	8	1.6	4.0	1011100011	101000000
834	COST OF PRIME COATS	2.7	1	2.7	2.7	10000	0
1264	NUMBER INJURIES EACH ACCIDENT/YR LAST 5 YRS	2.7	1	2.7	2.7		01000000000
79	TYPE OF MEDIAN BARRIER	2.7	1	2.7	2.7	10	0
306	FOUNDATION WIDTH	2.7	2	2.3	3.0	10000001000	0
642	PERCENT OIL USED IN ACP	2.7	3	2.3	2.9	10000010001	0
1234	PERCENT LANE MI OF PVMT WITH CURLING SLABS	2.7	1	2.7	2.7	10000000	0
1235	PERCENT LANE MI OF PVMT WITH FAULTING SLABS	2.7	1	2.7	2.7	10000000	0
1236	PERCENT LANE MI OF PVMT WITH SCALING SURFACE	2.7	1	2.7	2.7	10000000	0
1238	PERCENT LANE MI OF PVMT WITH DEPRESSIONS	2.7	1	2.7	2.7	10000000	0
1597	MINIMUM SERVICEABILITY INDEX	2.6	1	2.6	2.6	0	100000000
75	TYPE OF RAMPS	2.6	2	2.1	3.1	10100000000	0
684	TESTS FOR VISCOSITY OF ASPHALT CEMENTS	2.6	2	2.2	3.0	1001000000	0
680	MAX TENSILE STRENGTH OF ASPHALT MIX	2.6	1	2.6	2.6	100000000	0
974	RAINFALL AMOUNT FOR LAST YEAR	2.6	1	2.6	2.6	0	1000000
829	CENTER STRIPE COST PER MILE	2.6	1	2.6	2.6	0	10
828	COST OF SURFACE/CY	2.6	3	1.1	4.4	110001	0
324	DENSE DENSITY (DD) - BORROW MATERIAL	2.6	1	2.6	2.6	10000000	0
323	LOOSE DENSITY (DL) - BORROW MATERIAL	2.6	1	2.6	2.6	10000000	0
678	DAILY CONTROL TEST DATA (AVG)	2.6	1	2.6	2.6	10000	0
123	ALLOWABLE CONSTRUCTION INTERFERENCE TO TRAFFIC	2.6	3	2.2	3.3	10000000011	0
462	MINIMUM PLASTICITY INDEX - BASE	2.6	2	2.1	3.1	10000010000	0
647	TYPE OF ADMIXTURE USED	2.6	1	2.6	2.6	100	0
494	LOCATIONS OF CONC PVMT LESS THAN PLAN THICKNESS	2.6	1	2.6	2.6	10	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
794	PENETRATION COST/LANE MILE - CONSTRUCTION	2.6	1	2.6	2.6	100000 0
837	COST OF CONCRETE PLACEMENT	2.6	2	2.2	3.0	100001 0
655	SIEVE ANALYSIS OF MATERIAL IN ACP	2.6	1	2.6	2.6	10000000 0
685	STABILOMETER VALUES OF BITUMINOUS MIXTURES	2.6	1	2.6	2.6	1000000 0
1263	NUMBER DEATHS EACH ACCIDENT/YR LAST 5 YRS	2.6	2	2.5	2.7	10000000001000000000
869	COMPOSITE LABOR RATE-MAINTENANCE-PER CONST JOB	2.6	1	2.6	2.6	1000000000 0
873	COMPOSITE EQUIP RENTAL RATE-MAINTENANCE-PER CONST JOB	2.6	1	2.6	2.6	1000000000 0
868	DATE OF COMPOSITE LABOR RATE - MAINT	2.6	1	2.6	2.6	1000000000 0
36	LEVEL OF PEDESTRIAN TRAFFIC	2.6	2	1.3	3.9	100000000 100
414	SUBBASE FRICTION FACTOR	2.6	1	2.6	2.6	100000000 0
872	DATE OF COMPOSITE EQUIP RENTAL RATE - MAINT	2.6	1	2.6	2.6	1000000000 0
122	CONSTRUCTION UNDER TRAFFIC	2.6	1	2.6	2.6	100000000 0
877	IDENTIFICATION OF CONTRACTOR	2.6	10	1.5	3.2	11011011000111010000
331	SHRINKAGE LIMIT OF BORROW MATERIAL	2.6	1	2.6	2.6	10000000 0
985	ANNUAL FLOODING DATA	2.5	6	1.6	3.6	10000010100110010000
796	LAYER MATERIAL COST - CONSTRUCTION	2.5	2	2.3	2.8	1000000100 0
1296	DENSITY - SUBBASE	2.5	1	2.5	2.5	100000000 0
945	AVERAGE SUMMERTIME TEMPERATURE	2.5	10	.7	3.6	100011100011001110100
666	RATE USED FOR PRIME COAT ASPHALT (GAL/S.Y.)	2.5	4	1.4	3.9	11000011 0
330	PH VALUE OF BORROW MATERIAL	2.5	1	2.5	2.5	10000000 0
1035	TRAFFIC AT PEAK PERIODS	2.5	2	2.0	3.0	10000000001 0
876	CONSTRUCTION METHOD	2.5	1	2.5	2.5	10 0
619	WIRE MESH TYPE	2.5	1	2.5	2.5	1000000000 0
540	CURING COMPOUND	2.5	1	2.5	2.5	10 0
1060	MINIMUM DESIGN SPEED	2.5	1	2.5	2.5	0 100000000
891	TYPE OF PAVER	2.5	3	2.1	2.8	10000001001000000
8	PROJECT DESIGNATOR	2.5	1	2.5	2.5	1000000 0
818	COST OF BASE/LANE MILE - SHOULDER	2.5	1	2.5	2.5	10 0
826	COST OF SURFACING/LANE MILE -TRAFFIC LANE	2.5	1	2.5	2.5	10 0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
814	COST OF SUB-BASE/LANE MILE - SHOULDER	2.5	1	2.5	2.5	10	0
813	COST OF SUB-BASE/LANE MILE -TRAFFIC LANE	2.5	1	2.5	2.5	10	0
827	COST OF SURFACING/LANE MILE - SHOULDER	2.5	1	2.5	2.5	10	0
48	OVERALL VISUAL APPEARANCE OF HWY	2.5	2	1.8	3.2	1000000001	0
197	DITCH WIDTH	2.5	3	2.2	2.8	11100000000	0
950	PERCENT DAYS BELOW 32 DEGREES F	2.5	7	.8	3.6	1010001	101110000
311	MODULUS OF ELASTICITY OF NATURAL SOIL BELOW SUBGRADE	2.5	1	2.5	2.5	1	0
726	AGGREGATE TYPE FOR EACH REHABILITATION LAYER	2.5	2	2.0	2.9	10000100	0
517	AMOUNT OF ICE USED	2.5	1	2.5	2.5	1000000	0
88	NUMBER OF BRIDGES	2.4	2	2.3	2.6	01100000000	
933	ANNUAL AVERAGE TEMPERATURE	2.4	21	1.3	3.6	111111111111111111111	
316	COMPACTION EFFORT ON EMBANKMENT	2.4	1	2.4	2.4	100000000	0
665	RATE OF TACK COAT ASPHALT USED (GAL/S.Y.)	2.4	2	1.8	3.1	10000010	0
793	LAYER CONSTRUCTION COST	2.4	4	1.7	2.8	10010000001000010000	
1246	SWELL RATING (BI-ANNUALLY)	2.4	1	2.4	2.4	100000000	0
878	NAME OF RESIDENT ENGR ON PROJECT	2.4	5	1.8	3.1	110011000	10000000
1084	CONDITION OF SHOULDER (DEVELOP SUBJECTIVE RATING CODE)	2.4	1	2.4	2.4	100000000	0
1062	SPEED LIMIT	2.4	4	1.5	3.6	1000000000101001000000	
281	PLASTICITY INDEX OF UNSTABILIZED FLEX PVMT LAYERS	2.4	1	2.4	2.4	100000000	0
42	USE OF ADJOINING GROUND	2.4	6	1.7	4.0	100010010	111000000
235	SAND EQUIVALENT - LAYER	2.4	1	2.4	2.4	01000000000	
226	AGGREGATE DISTRIBUTION - LAYER	2.4	1	2.4	2.4	100000000	0
84	LOCATION OF CULVERTS	2.4	1	2.4	2.4	100000000	0
573	MODULUS OF ELASTICITY - LAYER	2.4	3	1.0	3.9	1100000000	100000
975	AVG DURATION OF EACH WET CONDITION	2.4	1	2.4	2.4	100000000	0
688	DUCTILITY OF ASPHALT	2.4	1	2.4	2.4	1000000	0
811	COST OF SUBGRADE STABILIZATION/SQ YD	2.4	1	2.4	2.4	01000000000	
45	ROADSIDE GEOMETRIC	2.4	1	2.4	2.4	100000000	0
333	SWELLAGE FACTOR	2.3	1	2.3	2.3	100000000	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS
91	LENGTH OF EACH BRIDGE	2.3	2	1.9	2.8	10000000000 1000
58	CLIMBING LANE LENGTH	2.3	1	2.3	2.3	0 100000000
879	NAME OF JOBSITE INSPECTOR	2.3	2	1.3	3.4	1001000 0
375	SPECIFIC GRAVITY OF SUBGRADE	2.3	1	2.3	2.3	10000000 0
165	SLOPE	2.3	8	1.4	3.4	1100101 111010000
127	EXTENT OF CUTS AND FILLS	2.3	1	2.3	2.3	0 100000000
160	GRADE LINE ACCEPTABILITY	2.3	1	2.3	2.3	0 10000
214	DEPTH FROM SURFACE - LAYER	2.3	1	2.3	2.3	10000000 0
941	DAILY TEMPERATURE RANGE	2.3	2	2.1	2.5	100000000 100000
18	LOCATION OF TRANSVERSE JOINTS	2.3	1	2.3	2.3	0 1000000
373	ERODABILITY FACTOR/SUBGRADE	2.3	1	2.3	2.3	100000000 0
1265	PROPERTY LOSS EACH ACCIDENT/YR LAST 5 YRS	2.3	1	2.3	2.3	01000000000
44	PARKING WIDTH	2.3	3	.9	3.4	110000000 100000000
117	SHOULDERS COLOR CONTRASTING OR EDGE STRIPED	2.3	2	1.8	2.8	100000000001000000000
788	COST OF ADDITIONAL RIGHT-OF-WAY	2.3	1	2.3	2.3	100000000 0
621	BOND STRENGTH OF CONCRETE TO STEEL - CRCP	2.2	1	2.2	2.2	100000000 0
937	TEMPERATURE (VARIATION)	2.2	3	1.6	2.6	01100010000
669	PERCENT MOISTURE OF BASE AT THE TIME OF PATCHING	2.2	1	2.2	2.2	0 1000000
1021	FREQUENCY OF 72,000 LB LOADS USING ROAD	2.2	2	1.7	2.7	10000 1000000
802	COST OF SUBGRADING	2.2	1	2.2	2.2	100 0
911	IDENTIFICATION OF SUPPLIER - PRIME COAT MATL	2.2	1	2.2	2.2	10 0
638	TYPE OF ASPHALT USED FOR TACK COAT	2.2	2	1.8	2.6	10100000000
1113	SKID RESISTANCE EACH HALF MILE/LANE	2.2	1	2.2	2.2	100 0
795	COST OF MATERIAL PREPARATION CONSTRUCTION	2.2	1	2.2	2.2	1000 0
502	BRAND OF CEMENT - CONCRETE PAVEMENT	2.2	7	.8	3.9	1001010110 100000001
409	MINIMUM PLASTICITY INDEX - SUBBASE	2.2	1	2.2	2.2	10000 0
189	TYPE OF EROSION CONTROL	2.1	5	.9	2.9	1110010000 10000000
1073	COMFORT FACTOR	2.1	1	2.1	2.1	01000000000
528	AGGREGATE PERCENT PASSING NUM 4 SIEVE - CONCRETE	2.1	2	1.4	2.9	1000010000 0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
1139	DEFLECTION MEASUREMENTS - EA 0.10 MI. BI-ANNUALLY	2.1	1	2.1	2.1	100000000	0
617	TERMINAL ANCHORS - NUMBER OF LUGS EACH END	2.1	2	.2	4.0	1010000	0
1271	RATE OF LIGHT PNEUMATIC TIRE ROLL (HR/MILE) - LAYER	2.1	1	2.1	2.1	10000000000	0
1270	RATE OF FLAT WHEEL ROLLING (HR/MILE) - LAYER	2.1	1	2.1	2.1	10000000000	0
1272	RATE OF EMBANKMENT SPRINKLING (GAL/CUBIC YD)	2.1	1	2.1	2.1	10000000000	0
1273	RATE FOR HEAVY TAMP EMB ROLLING (HR/CUBIC YD)	2.1	1	2.1	2.1	10000000000	0
1275	RATE OF SUBGRADE SPRINKLING (GAL/SQ YD)	2.1	1	2.1	2.1	10000000000	0
1276	RATE FOR HEAVY TAMP SUBGRADE ROLLING (HR/CUBIC YD)	2.1	1	2.1	2.1	10000000000	0
1274	RATE FOR MED PNEUMATIC TIRE EMB ROLLING (HR/CUBIC YD)	2.1	1	2.1	2.1	10000000000	0
1277	RATE FOR MED PNEUMATIC TIRE SUBGRADE ROLLING (HR/SQ YD)	2.1	1	2.1	2.1	10000000000	0
1282	RATE OF PNEUMATIC TIRE ROLLING TO BASE (HR/CUBIC YD)	2.1	1	2.1	2.1	10000000000	0
658	AGGREGATE SIZE FOR PENETRATION PAVEMENTS	2.1	2	1.0	3.2	11000	0
1278	RATE OF BASE SPRINKLING (GAL/CUBIC YD)	2.1	1	2.1	2.1	10000000000	0
1281	RATE OF FLAT WHEEL ROLLING TO BASE (HR/CUBIC YD)	2.1	1	2.1	2.1	10000000000	0
129	LOCATION OF FILLS ACROSS LAKES	2.1	1	2.1	2.1	0	1000000
782	SOURCE OF FUNDS	2.1	2	1.2	3.0	100000000	1000
962	PRECIPITATION FROM FIRST FREEZE TO LAST THAW	2.1	1	2.1	2.1	10000000	0
957	DATE OF FIRST FREEZE EACH WINTER	2.1	1	2.1	2.1	10000000	0
751	LEVEL-UP NUMBER	2.1	1	2.1	2.1	10000000	0
1226	AMOUNT OF RAVELING	2.1	1	2.1	2.1	1000000000	0
982	AVERAGE USE OF CHLORIDES	2.1	2	1.5	2.6	100000	1000000
641	TYPE OF OIL USED FOR ACP	2.0	2	1.5	2.6	10000000001	0
618	TYPE OF ANCHOR LUGS	2.0	2	.1	4.0	1010000	0
52	TYPE OF PAVEMENT MARKING	2.0	2	1.8	2.2	10100000000	0
1280	RATE OF HEAVY TAMPING ROLLING TO BASE (HR/CUBIC YD)	2.0	1	2.0	2.0	10000000000	0
1279	RATE OF TAMPING ROLLING TO BASE (HR/CUBIC YD)	2.0	1	2.0	2.0	10000000000	0
71	INTERSECTION DESIGN	2.0	1	2.0	2.0	100000000	0
298	KNOWN OR POTENTIAL CHEMICAL REACTION OF LAYERS	2.0	1	2.0	2.0	100	0
787	RIGHT-OF-WAY COST PER ACRE	2.0	1	2.0	2.0	0	1000

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
930	AVG MAX DAILY TEMP VARIATION OF PVMT SURFACE	2.0	1	2.0	2.0	0	1000000
300	EFFECTIVENESS OF MOISTURE BARRIERS BY LAYERS	2.0	1	2.0	2.0	100	0
695	SUSCEPTIBILITY OF ASPHALT TO ACTINIC SOLAR RADIATION	2.0	1	2.0	2.0	100	0
553	CONCRETE TEST PROCEDURES	2.0	2	.8	3.2	1000000010	0
376	PH VALUE OF EXISTING SUBGRADE	2.0	1	2.0	2.0	10000000	0
1284	BASE COMPACTED VOLUME (CUBIC YDS/STA)	2.0	1	2.0	2.0	10000000000	0
806	SUBGRADE COST/LANE MILE	2.0	3	1.7	2.3	100001000	100000000
70	TYPE OF INTERSECTION	2.0	1	2.0	2.0	100000000	0
980	AVERAGE NUMBER OF SNOWFALLS PER YEAR	1.9	1	1.9	1.9	100000000	0
988	ANNUAL NUMBER OF SUNSHINE DAYS	1.9	1	1.9	1.9	01000000000	
56	LOCATION OF CLIMBING LANES	1.9	1	1.9	1.9	100000000	0
339	NUMBER OF LAYERS - SUBGRADE	1.9	1	1.9	1.9	100000	0
468	PERCENT MOISTURE OF BASE AT TIME OF RECORD SAMPLES	1.9	1	1.9	1.9	0	1000000
1175	CRACKING PATTERN OF SUBBASE	1.8	1	1.8	1.8	100000000	0
616	NUMBER OF TERMINAL ANCHORS USED	1.8	3	.2	3.1	100001001000000	
706	NOISE LEVELS EXHIBITED BY SURFACE AGGREGATES AND DESIGN	1.8	4	1.0	2.6	1000011001000000000	
1094	SMOOTHNESS COEFFICIENT	1.8	1	1.8	1.8	01000000000	
805	COST OF EACH SHOULDER LAYER/SQ YD	1.8	2	1.8	1.8	10000000001000000000	
237	TYPE OF MIXING FOR EACH LAYER	1.8	1	1.8	1.8	0	100000000
892	TYPE OF MIXER	1.8	1	1.8	1.8	100	0
77	LOCATION OF MEDIAN OPENING	1.8	1	1.8	1.8	100000000	0
371	PERMEABILITY OF SUBGRADE MATERIAL	1.7	1	1.7	1.7	0	1000000
120	DIFFICULTY OF MODIFICATION	1.7	1	1.7	1.7	0	10000
276	MAX LL OF EACH LAYER	1.7	1	1.7	1.7	1000000	0
543	LOCATIONS OF CONC PVMT OPENED TO EMERGENCY TRAFFIC	1.6	1	1.6	1.6	10	0
958	DATE OF LAST THAW EACH SPRING	1.6	1	1.6	1.6	10000000	0
890	TYPE OF HAULING EQUIPMENT	1.6	1	1.6	1.6	0	1000000
934	SEASONAL AVERAGE TEMPERATURE	1.6	2	.9	2.2	10000	100000
369	TRIAXIAL VALUE VERSUS MOISTURE VARIATION BY LAYERS	1.5	1	1.5	1.5	100	0

(Continued)

TABLE F-1. (Continued)

ITEM	DESCRIPTOR	AVG	N	RANGE RLW	RANGE RHI	GROUPS	
349	RATE OF APPLICATION OF SUBGRADE MATERIAL STABILIZER	1.5	1	1.5	1.5	1	0
949	PERCENT DAYS ABOVE 95 DEGREES F	1.5	1	1.5	1.5	0	100000000
851	WET UNIT WEIGHT	1.5	2	.7	2.4	10001000000	0
990	AVERAGE WIND SPEED PER MONTH BY COUNTY	1.5	1	1.5	1.5	1000000000	0
266	THERMAL COEFFICIENT - LAYER	1.5	1	1.5	1.5	1000000000	0
46	TYPE OF ROADSIDE GROOMING	1.5	1	1.5	1.5	0	100000000
130	OVERFLOW SECTION	1.5	1	1.5	1.5	100000000	0
188	AVG NUMBER OF DAYS UNDERDRAINS FLOW	1.4	1	1.4	1.4	0	1000000
801	COST OF GRADING	1.4	2	.6	2.2	10100	0
22	LOCATION OF DECELERATION LANES	1.4	1	1.4	1.4	100000000	0
26	LOCATION OF RAILROAD GRADE CROSSINGS	1.4	1	1.4	1.4	100000000	0
28	LOCATION OF REST AREAS	1.4	1	1.4	1.4	100000000	0
880	NAME OF PLANT INSPECTOR	1.3	1	1.3	1.3	1000000	0
23	LOCATION OF LEFT TURN LANES	1.3	2	1.1	1.5	10100000000	0
24	LOCATION OF TRAFFIC ISLANDS	1.3	1	1.3	1.3	100000000	0
25	LOCATION OF SPLIT LEVEL LANES	1.2	1	1.2	1.2	100000000	0
69	TYPE OF PAVEMENT TRANSITION	1.2	1	1.2	1.2	100000000	0
986	ANNUAL AVERAGE SOLAR RADIATION	1.2	1	1.2	1.2	100	0
831	COST OF EROSION CONTROL/SQ. YD.	1.1	1	1.1	1.1	10000	0
774	LOCATIONS WHERE PAVEMENT HAS BEEN MUDJACKED	1.0	1	1.0	1.0	100	0
20	LOCATION OF RIVER CROSSINGS	1.0	1	1.0	1.0	0	100000
515	SOURCE OF MINERAL FILLER	.9	1	.9	.9	10	0
630	TYPE OF ACP MIXING PLANT (WT BATCHING OR CONTINUOUS)	.9	1	.9	.9	10	0
43	TYPE OF PARKING PERMITTED	.8	1	.8	.8	10000	0
847	AVG SPECIFIC SURF AREA OF CEMENT - CONCRETE PAVEMENT	.7	1	.7	.7	10	0
72	NUMBER OF MAJOR INTERSECTIONS	.5	1	.5	.5	10000	0
73	NUMBER OF MINOR INTERSECTIONS	.5	1	.5	.5	10000	0
27	LOCATION OF RUMBLE STRIP	.4	1	.4	.4	100000000	0
64	LANE NUMBER	.2	1	.2	.2	10	0

TABLE F-2. LIST OF REDUNDANCIES REPORTED DURING DELPHI PROCESS

Original number	Same as ( ) frequency
19	211
31	476
82	203
96	107, 437
98	99(2), 100(2)
135	137, 217, 224, 421, 424(3)
140	141
165	156, 167(3)
147	152
205	334, 383
211	212, 213(2), 419
217	305, 345, 387, 388, 420(2), 480(4), 491, 627, 757, 759
219	344(2), 392, 427
224	335(2), 384, 391, 626, 757, 759, 435
228	273, 438
246	249, 353, 447, 484
255	257, 273
263	359, 401, 455, 485
264	559
268	357, 451, 559
273	559
291	559
299	412(2), 903
306	341
312	335, 336, 366
317	353
335	366
336	360(2), 384
343	344(2), 348, 384, 392
360	367, 381, 383, 384, 387, 397, 402(3)
367	368, 372, 366

(Continued)

TABLE F-2. (Continued)

Original number	Same as ( ) frequency
397	384, 398, 399, 400
408	409
415	418, 435
418	417, 435(4), 436, 437
424	447
426	427(4), 430, 432, 433
435	436, 437
447	626, 649, 744, 745, 746
480	627, 491
464	277
477	649, 653
500	527, 528, 529
503	531(2)
507	508
509	510
519	520
564	566, 572, 575
565	570
588	598
589	602, 605
590	603, 606
592	596, 597
593	596, 597
594	596, 597
595	597, 596
611	601(2)
612	604(2)
625	626, 633, 673, 674, 675
667	669
682	683
688	689
692	693

(Continued)

TABLE F-2. (Continued)

Original number	Same as ( ) frequency
791	792
793	798, 820, 821, 825, 843, 844
806	807, 808, 809
810	816
819	821
851	854, 862, 853
882	890, 891
907	908, 910
903	912
933	936, 938(2), 947, 948, 992, 945, 1298
935	936, 947, 948
954	955(4)
964	967, 968, 1299
993	1013, 992, 996
1039	1044
1012	1014(2)
1013	1016
1092	1098(2), 1099, 1102
1109	1113, 1114(2)
1114	1108, 1109, 1110
1138	1140
1251	1252, 1253, 1254

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